University of Delaware, Senior Design Team 10

Memo

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CC: Dr. Glancey, Dr. Keefe, Dr. Wilkins

Date: December 12, 2004

Re: Phase 3, Proof of Concept Prototype

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Problem/ Background

Terumo is a Japanese based medical supply company. They asked our team to design, test, and build a prototype that can mass clean medical catheters. A medical catheter is a long, flexible, hollow, plastic rod designed to fit into arteries in the human body. Once inserted, the interior portion of the catheter is removed, leaving a pathway into the body. At this point the physician can either insert a micro-camera or any other type of medical tool that they see fit.

The current tubing dimensions range from about 18" to 41" in length. The internal diameters range from about .02" to .01", and the external diameters range from .07" to .124". At the end of each catheter is a generic fitting, used for securing in a luer lock.

Currently, the catheters are washed internally by flushing the inside with AK-225 solvent for several seconds. The exterior of the catheters are cleaned manually, by a trained operator who soaks a Bemcot (lint free cotton) cloth in AK-225 solvent. This operator must scrub the length of each individual catheter, performing a very tedious and time-consuming operation. It would be advantageous to incorporate a machine that could clean the catheters, minimizing the amount of work that the operator would have to do. Ideally, the operator would be able to perform a completely separate task simultaneously, maximizing the amount of work out of this individual and saving Terumo money on hiring a separate employee to perform the other task. Also this change to an automated system will provide an ergonomic improvement by reducing repetitive motion, standardize the cleaning method, and increase throughput.

Wants/Constraints/Metrics/Target Values

We have compiled a list of wants and constraints from talking to personnel at Terumo Medical, from observing the current cleaning process and from a list of requirements given to us from the Terumo Medical Corporation. Using the UDesign process we were able to decide what our most important wants were. We then came up with a list of metrics to quantify each want. At this point we came up with a list of target values for each metric that our concept must fulfill. Directly below is a chart (Table 1) describing our most important wants, with the metrics and target values, in their order of importance (#1 being most valued, and #11 being the least valued)

Table 1

Want	Want Description	Metric	Target Values
1	Operator Safety	Amount of solvent/vapors contained	100%
		Safety lock out devices	Wherever Possible
2	Catheter undamaged	Radius of Curvature	20" or more
3	Cleanliness	Percentage of lubricant that will stick	100%
4	Ease of use	The number of operations the operator must perform	5
5	Speed of use	Throughput	500 parts per hour
		Length of time from start to finish of operation	less than 30 seconds
6	Low maintence	How often the machine must be stopped for cleaning	once per day
7	Effective Filtration device	The size of the filter used to filter air and solvent	10 microns
8	Recycling of Solvent	How much solvent is permissible to lose	less than 1.5 gallons per week
9	Ergonomically pleasing	Operator Reaching angle	less than 15 degrees from horizontal
10	Low cost	Overall price	approx. $2000
11	Small Size	The overall size of the machine	3' by 5' or smaller

1-Operator Safety: The AK-225 solvent can be very harmful to the operator if the operator's skin comes in contact with it. For this reason the safety of the operator is the most important component of the design criteria. Also, if operating conditions are determined to be unsafe, the machine won't be able to be used at all.

2- Catheters undamaged: During the loading of catheters, the catheters will be bent to a certain degree. If the Catheters are bent too far, then they will not restore to their original (straight) position when relaxed. The target value was given to us from Terumo.

3- Cleanliness: We want the catheters to be as clean as possible so that the coating will stick. Our goal is to completely coat the catheter.

4-Ease of Use: We want our washer to be easier to use than the current method of hand washing, the operator must currently makes about 5 operations. Our goal was to at least match the number of operations currently done.

5- Speed of use: Currently, hand washing takes about a minute for each catheter, in order to meet throughput requirements we will have to cut this time in half.

6- Low maintenance: Terumo asked that the machine only need to be shut down and cleaned once a day for cleaning.

7-Effective filtration device: A good solvent filtration device is crucial to good cleanliness. The solvent will be removing silicon residue as well as particulates. A 10 micron filter was recommended by Terumo for removing these particles from the solvent.

8- Recycling of solvent: The solvent is very expensive and it is crucial that as much of it is retained as possible. Currently Terumo wastes about 1.5 gallons of solvent per week. We would like to at least equal this amount, if not lessen it.

9-Ergonomically Pleasing: It can be uncomfortable to repeatedly have to reach to high extremities, so we want to minimize this amount. After pretending to be operators for several minutes we decided that an arm angle of no higher than 15 degrees to the horizontal would be an acceptable angle.

10- Low cost: We wanted to spend as little money as possible, however Terumo agreed to give us $2,000 for the project.

11-Small Size: Clean room real estate is highly valuable and we wanted to minimize the amount of space that our machine takes up. Terumo agreed that a 3' x 5' footprint would be acceptable. The machine will have to be slightly longer than the tallest catheter, our target value is to minimize this height.

Initial Concepts

Using these metrics and constraints we were able to develop two general categories of cleaning methods, cleaners that would use a wiper in contact with the catheter to clean the outside, and a method that would use pressurized solvent sprayed on the catheter to clean the outside. All of these methods, use a luer lock to secure the catheter. These luer locks have a central tube that is used to deliver the solvent, AK-225 to the inside of the catheter.

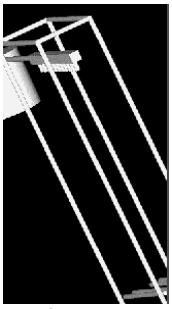


Figure 1

The first concept developed was the Vertical Rotating Washer (Figure 1), which would hold several catheters vertically and rotate them along their axis as pairs of bemcot rollers clean the length of the catheter. This rotation allows for all sides of the catheter to be cleaned with one pass. With this method of cleaning there was concern that damage to the catheter would occur because of the speed that the catheter would need to rotate at while also being pinched. Also after some sourcing of material it was determined that it was to complicated and expensive to purchase the fittings needed.

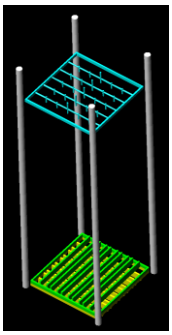


Figure 2

The second concept was Non-Rotating Vertical Washer (Figure 2), this concept removed the need for rotation by having two pairs of bemcot rollers perpendicular to one another traversing the length of the catheter, cleaning the whole surface in one pass. After 10 passes with the scrubbers the bemcot cloth would have to be replaced. This would be an awkward and time consuming process due to the scrubber orientation; thus making this design less desirable.

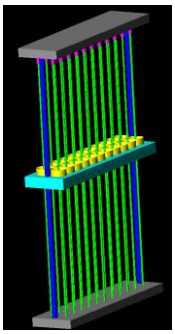


Figure 3

The third concept was the Power Washer (Figure 3), which used an array of jets around each individual catheter these jets are held within a manifold that would move over the length of the catheter. This would clean by spraying AK-225 solvent at high velocities against the surface. During the spraying process some of the AK-225 would become vaporized and pose a health risk to the operator. Also because of this vaporized state recapturing the AK-225 would be difficult.

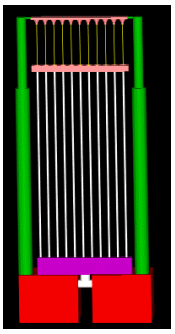


Figure 4

The fourth concept was the Submerged Pressure Washer (Figure 4), in which each catheter is placed in a tube, and pressurized solvent is passed through this tube, thus cleaning the external surface. This concept provided a better solution because it removed the need for bemcot cloth, kept the AK-225 completely contained, and made the recirculation process easy.

Chosen Concept

After examining each of the concepts with respect to metrics and the UDesign process it was determined that the Submerged Pressure Washer was the best design. This design rated well mainly because of its lack of moving parts, and because it contained the solvent through every step of operation, making it a safe and efficient machine. We assumed that all concepts would

fulfill the other metrics evenly. In order for the design to be put into use, it had to be slightly redesigned from the initial concept (Figure 4). The redesigning was primarily due to budget constraints so the system was change to show how the process would work on a smaller scale. As a result of discussion instead of cleaning 10 catheters of both the 18" and 41" variety, we would clean 2 of the shorter catheter (Figure 5). Also instead of using the device in the manufacturing line it will be used to further develop this new method of cleaning.

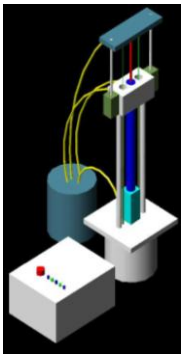
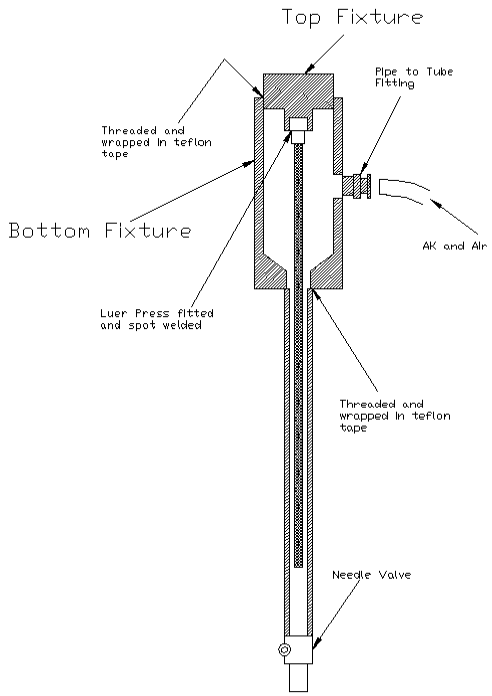


Figure 5

Validation of Concept

The Submerged Pressure washing idea, as far as we know, has never been used to clean medical catheters. In order to determine whether or not this method would be effective in cleaning catheters, a test had to be performed. To test the Submerged Pressure washing system, we built a fixture that would clean one catheter in the same way that our prototype would clean several catheters at once. We built a device much like the one shown in Figure 6.

Figure 6



The catheter is placed within a hollow chamber and down the length of a hollow tube. Solvent will be run through the system, cleaning the outside of the catheter as it passes by. Our intended method of cleaning the outside of the catheter is to use pressurized AK fluid combined with air to disengage dirt from the surface, and carry it away. We also incorporated a valve at the bottom of the hollow tube, when this valve was closed the fluid would remain stagnant around the catheter. Our belief was that this pressurized fluid could help the solvent break up any dirt on the surface. Then for cleaning the inside of the catheter, we will use the current method in the testing apparatus. For this reason the catheter is not going to be cleaned on the inside for testing.

The test for cleaning the outside of the catheter requires two preliminary steps, and then a variety of flow control variables will be applied; in order to determine which combination cleans the catheter best. First, the catheter needs to be twisted into the leur lock that has been mounted into the top fixture. The top fixture and bottom fixture have been threaded to fit together. After wrapping the top fixture in Teflon tape, the operator will screw the two pieces together. Once these two setup steps are complete, the operator may clean the catheter.

Results of Testing Concept

On October 14, 2003 our team visited the Terumo Medical Corporation to test the submerged pressure washing system. Terumo had prepared a number of catheters with a thin layer of silicon on the bottom 5 centimeters. The lubricant that needs to be applied to these catheters will not stick to this silicon, so if we could successfully remove this layer of silicon, then the cleaning was considered successful. In order to test if the silicon was removed, after cleaning and coating, the catheters were submerged in Congo red dye. This dye will not stick to the silicon coating. After submersion in the dye, any spots that are not red were not cleaned thoroughly.

Due to safety concerns, the test was performed in a room with a smaller level of compressed air than we originally anticipated. We were planning on varying the amount of pressure applied to the tank between 40 and 60 psi. However, the room that we were placed in only had air pressure available up to 38 psi. Our Team decided to go ahead with our testing anyway, to see if the Submerged Pressure Washing system would work at this lower pressure. We tested cleaning the catheters in a few ways with or without back pressure (the closing of the valve on the bottom of the tube), mixing air with the solvent, and we experimented with different time durations of each step. When all was said and done, 8 catheters were cleaned with a combination of these variables.
The chart below shows the different variable combinations that were tested and the results of each (Table 2).

Table 2

Tests Conducted with AK 225 solvent at Terumo Medical Submerged Pressure Wash System

Test #	Pressure	Step 1	Step 2	Step 3	Small spots missed	Large spots missed	Tip Cleaned (Y/N)
1A	38 Psi	Catheter was submerged in pressurized Solvent (10 seconds)	Catheter was dried with Air (10 seconds)		5	0	Y
1	38 Psi	Catheter was submerged in pressurized Solvent (10 seconds)	Catheter was cleaned with solvent (10 seconds)	Catheter was dried with Air (10 seconds)	0	1	N
4O	38 Psi	Catheter was cleaned with solvent (20 Seconds)	Catheter was dried with Air (10 seconds)		3	1	Y
4G		Catheter was cleaned with solvent (10 seconds)	Catheter was dried with Air (10 seconds)		0	3	N
5	38 Psi	Catheter was submerged in pressurized Solvent (20 seconds)	Catheter was cleaned with solvent (10 seconds)	Catheter was dried with Air (10 seconds)	1	3	Y
7	38 Psi	Catheter was cleaned with solvent and air combination (10 seconds)	Catheter was dried with Air (10 seconds)		2	0	Y
8	38 Psi	Catheter was submerged in pressurized Solvent (10 seconds)	Catheter was cleaned with solvent and air combination (10 seconds)	Catheter was dried with Air (10 seconds)	3	0	N
9	38 Psi	Catheter was submerged in pressurized Solvent (15 seconds)	Catheter was cleaned with solvent and air combination (15 seconds)	Catheter was dried with Air (10 seconds)	1	3	N

* a small spot is defined as a spot less than approximately 4 mm^2, and still visible to the human eye
* a large spot is defined as a spot larger than approximately 4 mm^2

It can be seen that trial #7 cleaned the catheter most effectively. Trial 7 used a combination of air and solvent to clean the catheter, without the use of back pressure. From the results of testing, it was concluded that back pressure was not an effective means of cleaning the catheters. We theorize that the back pressure actually pushes the dirt further into the catheter surface, and does not help to remove it.

Proof of Concept Prototype (components and explanation)

How the following list of materials is incorporated into the current scaled down design can be seen or referenced in the assembly drawings in Appendix A

Tanks

Need two sealed Pressure vessels to hold at least 1 gallons of AK fluid each. The vessels must be fluid tight, have an interior surface compliant with AK fluid, be able to with stand ~80 psi, and must be contain appropriately sized and threaded holes to meet our needs. See assembly drawings in appendix A

-The reason that the each vessel needs to hold 1 gallons of fluid is because we approximated the amount of fluid to clean one catheter (from the actual testing done at Terumo) to be about a quarter of a gallon. We set ourselves a goal to clean two catheters at once for the prototype, so for every time the machine goes through its cycle, about.5 gallons is used. The reason for the over estimation, is that there needs to be a sufficient amount of room for the air to escape by way of the relief valve, therefore we factored I a safety factor of two.

-The reason that we need two vessels is that one vessel needs to pump the fluid through the system, and the other vessel will have to catch the fluid during a given cycle.

-The reason that each vessel needs to be air tight is because we intend for all of the fluid in the system to be completely contained or controlled at all times. Also we intend to use pressurized air in order to move the solvent through the system. Both tanks required welding in order to be air tight. See appendix E for analysis of weld size, and the engineering drawing of the base plate in appendix A.

-The interior surface of the vessel needs to be compliant with the AK fluid, because if the AK fluid destroys the material, the vessel could be destroyed or leak. Also, contaminants could break off of the vessel and flow across the catheter.

-The reason that each vessel must be able to withstand 80 psi of pressure is because that is the guaranteed pressure given by the in-house air, and ideally we'd like to try as many combinations as possible with pressure as a variable to determine the most effective fluid flow to clean the catheter. Also, for safety purposes, if the system is only designed to withstand 50 psi, if the regulator valve breaks, and 80 psi is introduced to the system, we wouldn't want a catastrophic failure to occur.

-The reason that we need the certain threaded holes to be imbedded into the vessel is that we need fluid to flow through it, and be sealed to designed or

purchased outlet fixtures. (This could also be accomplished, by drilling into the vessel and welding on appropriate fixtures.) See appendix A assembly drawings.

Pipes

Need 2 different 2 foot long 1/8" NPT threaded pipes with an inner diameter of .215" to contain catheters during operation. See assembly drawings in appendix A.

-The reason that 2 pipes are needed is because as designated earlier in the design process 2 catheters per cycle would be an effective solution to our problem of making a prototype to demonstrate how we intend our larger system to work.

-There are a few reasons why we decided that the pipes should be 2 feet long. The longest catheter that must be cleaned is ~1.5 feet, and we don't want the end of the longest catheter to be near the end of the pipe because the flow conditions close to the end of the pipe are radically different than those along its length. We would like to assume close to constant pressures and velocities across the surfaces that must be cleaned, so as to maintain control over the variables that govern the cleaning of the catheter. Also, because the most crucial section of the catheter that must be cleaned is at the end or tip, we would like to have particularly good control of the flow at that section of the pipe.

-The reason that we would like to use 1/8" NPT pipe with a .215" inner diameter is that this size pipe worked during the testing phase, and we couldn't think of a reason to input another variable into deciding which conditions (diameter of pipe, velocity, pressure, etc.) clean the catheters best.

Machined Manifold (Bottom Fixture)

The machined manifold must serve 5 separate functions. It must first make it possible for the top part of the catheter (with ½" width) to fit into the sealed enclosure. Secondly, the machined manifold must be compliant with the air regulator valve attached to the air distributing manifold. The third function that the machined manifold must have to be compliant with the manifold for distributing the AK fluid. Next, the machined manifold must be shaped so that the tip of the catheter is not damaged during loading. Finally, it must be able to fit and seal with the top fixture so that no fluid leaks from the system during operation. All of these reasons govern the design of our machined manifold (Appendix A).

Air Regulator Valve for Bottom Fixture

We need an air regulator valve in order to control the size of the air bubbles going into each 1/8” NPT pipe, so as to ensure consistency in the cleaning of the catheters in the system.

-The reason that we need a regulator valve to control the air flow into each catheter containing tube is that we need to control the air to AK fluid ratio used for the cleaning of each catheter. The reason that the regulator valves are used, instead of just opening a ball valve to allow the air to mix with the fluid, is that the regulator valve allows more precise control of the size of the air bubbles that are induced into the fluid flow. The air bubbles are what create or regulate the amount of turbulence in the flow, so to just open a relatively large valve (i.e. ball valve) to let air mix in with a flow of AK fluid is a process that is difficult to control. This will cause a lot of inconsistency in the mixed fluid flow along the lengths of the pipes. Also if we find that the size of the air bubbles must be changed throughout the cycle then we will be able to do so with these valves.

Air manifold for Bottom Fixture

To connect all of the air valves to the pressure source by way of piping or tubing would be extremely inefficient. For this reason, a manifold to distribute the air to all of the air regulator valves will be used to connect the air flow from the pressure source using only one tube. So, we need a manifold to distribute the air, with two 1/8” NPT pipe fittings, and a 5/8” tube fitting. Because, our prototype only cleans two catheters, we could simply use a T-joint as the manifold. For mechanical drawings refer to appendix A

-The reason for the two 1/4” NPT pipe to tube fittings is to attach the air regulator valve to the manifold.

-The reason for using a 5/8” tube fitting to input the air from the pressure source is to minimize head-loss between the pressure vessels and the regulator valves. Keeping the cross sectional area between the flow coming into the manifold close to the cross sectional area of the flow going out of the manifold should help to minimize this problem. Also, all of the tubing is already 5/8”, so it is just easier.

Fluid Manifold for Bottom fixture

We need a manifold to distribute the fluid from the pressure source. The fluid distributing manifold must have 2- 1/4” NPT pipe fittings and a 5/8” tube fitting. Again, because our prototype only cleans two catheters, we could simply use a T-joint to act as a manifold. For mechanical drawings refer to appendix A.

Note: Understanding fluid flow, specifically the mixture of air (which is usually compressible), and liquid AK (liquid fluids, like water, are usually incompressible) is extremely difficult to grasp quantitatively (even for experts in the field), so minimizing the variable to control this flow is of the utmost importance to us in order to utilize this technique as a cleaning mechanism.

Upper Manifold (Top Fixture)

We need a manifold for the top fixture to have 2 luer lock fittings and 4 1/4" NPT pipe to tube fitting. The top manifold must also be able to be fixed securely to an air cylinder to ensure controlled motion and forces applied to the manifold. For mechanical drawings, refer to appendix A.

-The reason that the manifold must have 2 luer lock fittings is because the tops of the catheters are designed to fit an ISO-495 luer fitting which ensure that the fluid that flows through them is completely contained.

-The reason that the manifold must have an opening to fit four 1/4" NPT pipe sized fittings to 5/8" tube fittings is that these are the sized fixtures used throughout the system.

Pneumatic Cylinder

Need an air cylinder to control the motion of the top fixture. The piston must reach as high as 1.5 ft and as low as 0 ft. The piston needs to provide enough force to seal the top and bottom fixtures fluid tight.

-The piston must have a 1.5 foot range because this is the distance the top fixture must travel per cycle. And the amount of room required for loading and unloading the catheters

-The pneumatic cylinder was not long enough to breach the gap between the upper manifold and the base plate. Therefore a cylinder support extension was created. For mechanical drawings see appendix A.

Valves

-Two check valves to connect 1/8" NPT pipe to catch tank, and cut off flow if necessary.

-Three valves to connect 5/8" tubing to tanks, and cut off flow or allow flow when necessary to both top and bottom fixtures. (One solenoid for fluid going to both top

and bottom fixtures, and each of the fixtures has its own air input, controlled by a solenoid valve on the pressure tank.)

-One valve to open or close the tubing connection between vessels to control the direction of pressurized air from the pressure source between the two different vessels.

-Two relief valves for each of the tanks so that pressure can be released from the system incase something were to go wrong.

-Two solenoids to determine when in-house air is allowed to pressurize each tank, by sealing off the tank being pressurized, and creating atmospheric conditions in the other tank so flow occurs.

Pressure Regulators

Need a pressure regulator to connect to in-house air so that the pressure going into the system is controlled at all times. Also, need another pressure regulator to connect the in-house air to the cylinder to regulate the pressure in it at all times.

Tubing

We approximate that we needed 6 feet of 1/8” tubing and ~25 feet of 5/8” tubing. These estimates are based on the number of tubes and pipes that run between the tanks and the various fixtures, and there respective length are estimated to be 3-4 feet long if the tubing is going to the bottom fixture, and 5-6 feet long if the tubing is going to the top fixture.

Electronic Components

Equipment list

Located within the electrical enclosure (see appendix C) is One (1) PLC, ten (10) Relays, three (3) Bridges, five (5) lights, One (1) Emergency Stop Switch, One (1) Toggle switch, and two (2) Mushroom Switches.

Problem/Solution

Due to our limited budget, we were only able to purchase solenoids that operate on a 12V DC 1.5 Amp current. However, our PLC operates on a 24V DC .5 amp source. The solution we chose to take was to incorporate ten (10) separate relays that are activated by a 24V DC .5 Amp source, but will pass a 12V DC 4 Amp current.

Solution Description for Supplying Power

A plug caring a 120 V AC current will first enter the enclosure and connect to the Emergency Stop button. Exiting the stop button, the current will branch into two separate wires. One wire will go to power the Toggle switch for the pneumatic cylinder and the other will go to power the PLC. The Toggle's neutral line will connect to the PLC's neutral.

We are delivering a 12V DC 1.5 Amp source via, a typical automotive car charger. The Car charger converts 120V AC current into 12V DC current. The positive cable of the car charger in ran through the enclosure and connected to a 10 Amp fuse. The fuse is then connected to a bridge that will distribute the 12V DC current to each of the #1 inputs of the ten (10) relays. Each of the Relay's #3 inputs will be connected to it's designated solenoid, solenoids, and lights. Each of the solenoid's grounds will be ran back into the enclosure and connected to a bridge. The bridge is then connected to the negative output of the car battery charger, there by completing the circuit.

The PLC Outputs

(For PLC Code, Refer to Appendix C)

The PLC outputs 1000-1004 & 1007-1103 will exit the PLC and connect to each of the corresponding Relays in the #2 position input. The PLC will be passing 24V DC .5 Amps to each Relay. Since the PLC outputs act as a ground, the Relay's #7 inputs will be connected to the 24V DC Bridge, which is being powered by the PLC's 24V DC output.

The PLC Inputs

(For PLC Code, Refer to Appendix C)

The PLC input 0000 is connected to sensor 1. Sensor 1 detects weather or not the cylinder is open using a magnetic switching mechanism. Input 0001 is connected to sensor 2. Sensor 2 detects weather or not the cylinder is closed using a magnetic switching mechanism. Input 0002 is connected to the start switch and input 0003 is connected to the reset button.

Solenoids

There are a total of eight (8) normally closed solenoid valves. All valves are composed of a Delrin enclosure with Teflon washers. A 12V DC 1.5 Amp current powers each valve. Six (6) valves have a ¼" diameter hole, and two (2) have a ½" hole.

Switches

The Start switch is red in color and is normally closed. The Reset button is black in color and is normally open. The Emergency Stop button is red and black in color and is set up to be normally closed.

Prototype Cost

The following is a general listing of the cost of the materials used. For a more complete listing see Appendix B.

Pressure Tanks (2) = $200 x 2= $400
Solenoid Valves (9) =$34.38 x 9= $309.42
SS 1/8" NPT Pipes (2) =$23.30 x 2=$46.60
Check Valves (2) = $40.42 x 2= $80.84
Pop-it Relief Valves (2)= $63.19 x 2= $126.38
Pressure Regulators = Free (in house)= $0
Upper/ Lower Manifold= Free (material in house, machining in house)= $0
Fittings ≈ $300
Air Cylinder= Free (in house) = $0
Pressure Regulator = $0
SS Stock = Free (in house) = $0
Tubing (25 ft) = $3.83 x 25 = $95.75
Electrical= Donation= $0
Miscellaneous Parts= $940

Total =$2000

Order of Operations

Note: For a complete user manual and maintenance manual, see Appendix D, and for reference of parts see Figure 7.
Note: Process is started when the pneumatic cylinder is in the open position.

1. Verify that the "Load/Remove" light is illuminated.
2. Load the catheters into their designated positions, by inserting the thick end of the catheters into the lure locks and giving them a quarter turn.
3. Remove your hands and (or) any other obstruction from the "Upper" and "Lower" manifold.
4. Lower the pneumatic cylinder by pressing down on the toggle switch in the direction labeled close.
5. When the "Closed" light is illuminated, lock the two safety latches located on the sides of the "Lower" manifold
6. Press the Start button
    a. Now the PLC program has been activated and the "Operating" light is illuminated.

b. The “Air In Pressure Pod” and “Pressure Relief Catch Tank” valve is energized. This will allow the pressure pod to build up pressure before running.
c. After five (5) seconds, the “AK Out” and “Air Out Lower Manifold” valves are energized. This will send AK to both the Upper and Lower manifolds, there by cleaning both the inside and outside of the catheter. Air is also being sent to the Lower manifold to insure a turbulent flow.
d. After fifteen (15) seconds, the “AK Out” valve is de-energized and the “Air Out Upper Manifold” valve is energized. This will stop the flow of AK and only run air through both the inside and outside of the catheter.
e. After five (5) seconds, the “Air in Pressure Pod”, “Pressure Relief Catch Tank”, “Air Out Lower Manifold” and “Air Out Upper Manifold” will be de-energized. The “AK Transfer”, “Air In Catch Tank”, and “Pressure Relief Pressure Pod” valves will be energized.
f. After 20 Seconds, the “AK Transfer”, “Air In Catch Tank”, and “Pressure Relief Pressure Pod” will be de-energized. The “Finish” light will be illuminated and the “Operating” light will be de-illuminated at this point, verifying that the process has been completed.

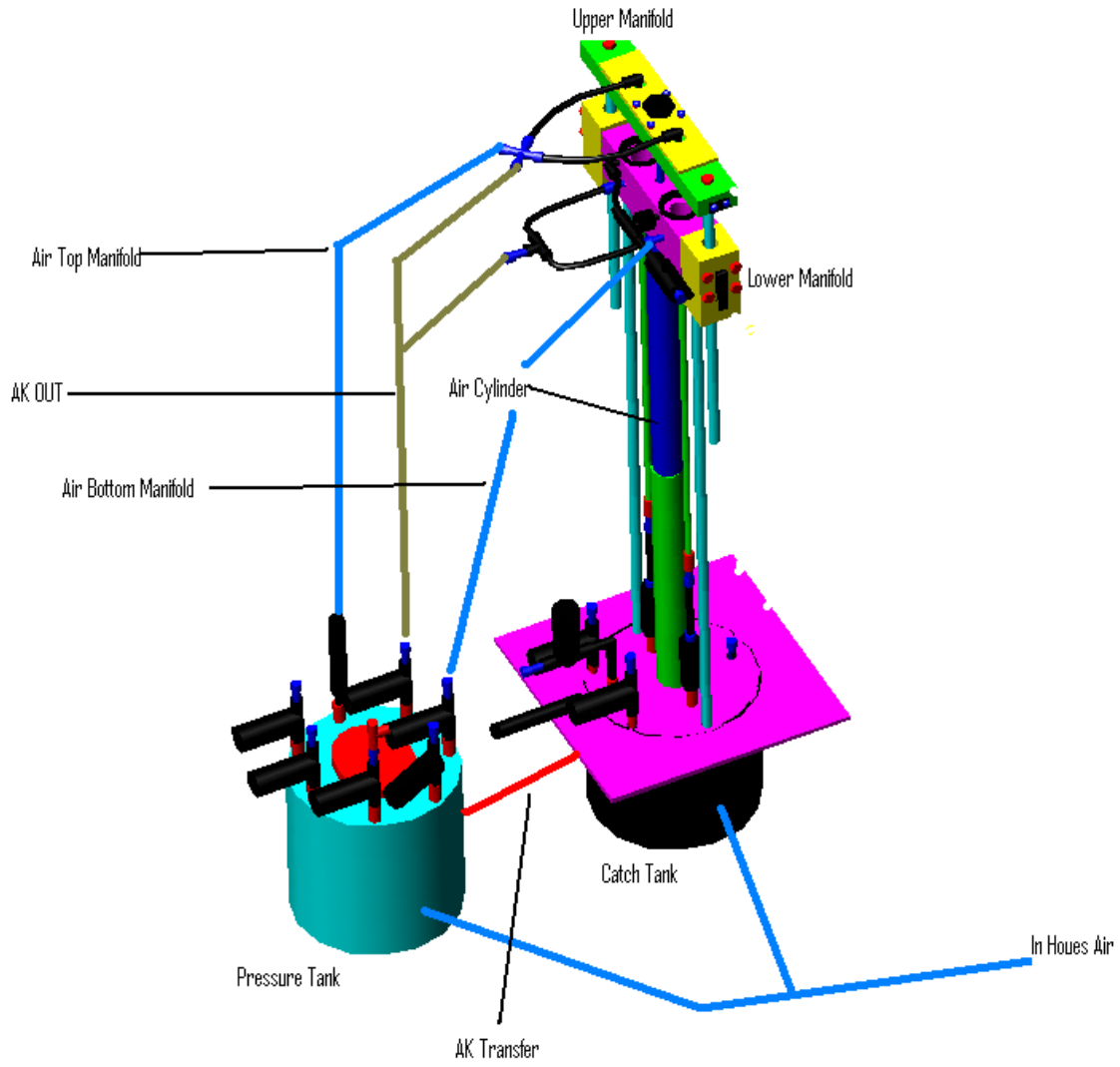
7. Once the “Finish” light has been illuminated, remove the Safety latches.
8. Remove your hands and (or) any other obstruction from the “Upper” and “Lower” manifolds.
9. Raise the pneumatic cylinder by pressing up on the toggle switch in the direction labeled open.
10. When the “Load/Remove” light is illuminated, remove the cleaned catheters.
11. If the AK fluid level needs to be checked, the “Check AK” light will be illuminated at this point.
    a. Unplug the machine and (or) hit the “Emergency Stop Button”
    b. Press the manual pressure relief button located on top of the pressure pod
    c. Remove the lid
    d. Check the AK level (Add as needed)
    e. Lock the lid back onto the pressure pod
    f. Re-Plug in the machine and or pull out the “Emergency Stop” button
    g. Hit the “Reset” button, the “Check AK” light should be de-illuminated at this point.
12. The machine is now ready for its next run.

*Note 1: If at any point during the running of the machine the sensor #2 is de-activated, symbolizing that the cylinder is being opened” the machine will come to an abrupt stop. If this occurs, press the Manual Pressure Relief Valve buttons located on the top of both the Pressure Pod and the Catch Tank. Correct the problem and press the “Start” button to continue the process from the beginning.

*Note 2: If the cylinder is in the open position and the start button is pressed, the machine will not start.

*Note 3: If the machine has already gone through its cleaning process, it cannot start up again until the Cylinder is raised again and the catheters are removed.

Figure 7



Testing of Proof of Concept Prototype

Initial testing had been done early on to make sure the submerged pressure washing method would work. After assembling the proof of concept prototype and pressure testing it for safety, we had a device with more accurate timing controls. So we conducted the same dye test as we used before, except this time using the prototype. During the testing we noticed that the flow of AK-225 to the 2 catheters being clean was different therefore each of the test specimens was labeled with its trial number and the letter “L” or “R” signifying left or right. This left or right orientation is determined by the operator’s point of view with respect to the front of the prototype (the “front” is the side on which no tubes connect to the lower

manifold. A total of seven trials were conducted with 2 catheters each, for these trials the amount of air mixed into the outside flow and the length of cleaning was varied. The air pressure used for all of these trials was 40 psi, which was the same about of pressure used in the verification testing. The results are summarized below in table 3. The primary goal of the cleaning process was to clean 100% of the tip and have spots smaller then 2mm in diameter elsewhere.

Table 3

Trial	Cleaning Time	Tip Clean?	Other Spots	Other Comments about Trial
1-L	20 seconds	N	N	AK only, no air mixing on outside
1-R	20 seconds	N	N	AK only, no air mixing on outside
2-L	20 seconds	N	2 spots, 2+ mm in dia.	AK and Air mix
2-R	20 seconds	N	N	AK and Air mix
3-L	20 seconds	N, small spots	N	AK and Air mix, too much air
3-R	20 seconds	Y	3 spots, 2 mm in dia.	AK and Air mix, too much air
4-L	25 seconds	Y	N	AK and Air mix, too much air, cycle stopped and restated
4-R	25 seconds	N, small spots	N	AK and Air mix, too much air, cycle stopped and restated
5-L	25 seconds	N	N	AK and Air mix
5-R	25 seconds	Y	N	AK and Air mix
6-L	30 seconds	Y	N	AK and Air mix, cycle stopped and restarted
6-R	30 seconds	Y	2 spots, 1mm in dia.	AK and Air mix, cycle stopped and restarted
7-L	30 seconds	Y	N	AK and Air mix
7-R	30 seconds	Y	N	AK and Air mix

*see figure 8 for a picture of trial results 7L

From these results it was determined that air mixed with AK-225 was necessary in order to clean the outside of the catheter. Also we found that the controlling of the air mixing was necessary; because too much air tended to produce spots along the catheter length or caused the tip to not be cleaned. We also determined that the longer cleaning time of 30 seconds, overall produced the best results. Further testing will have to be done with a more accurate valve in order to determine the correct rate of mixing for the air and AK-225.

Figure 8

After testing this system and seeing how it performed conclusion can be drawn about the performance of this system with respect to the metrics and target values we set forth at the beginning of this design process. Our most important want was operator safety; from this two metrics were developed amount of solvent vapor contained and safety lock out devices.

This prototype contained and controlled the solvent vapor during the cleaning process and after by venting the hazardous vapors to a fume hood.. Within the PLC control system safety lockouts were included, for example the cleaning process would not run if the pneumatic cylinder is in the open position. Also an emergency stop button was included on the control panel itself, incase the operator has to stop the process for some reason. These safety lock outs are good but more should be added for increased operator protection (see future plans for listing). The second most important want was that the catheters must be undamaged at the end of the process. From this we derived the metric/target value of radius of curvature greater then 20". If the radius is smaller then this value, the catheter will be permanently bent and un-useable. In the developed prototype the radius of curvature used to load and unload the catheters is about 30". Then the next most important want is cleanliness, the target value for this is that the tip is coated and there are no spots larger then 2mm in diameter along the length. The cleanliness results are summarized in table 3, further testing with higher pressure and a more precise air mixture is necessary in order better determine the exact specifications of the washing process. Then there is the ease of use, which is measured by the number of operations that an operator must perform in order to get the process started; our target value for this was 5 or less operations. The system we developed has exactly 5 operations: load, open/close cylinder, open/close latches, hit start button, and unload. The rest of the metrics developed involve taking measurement, and long term use of a full scale device. Thus they are not applicable to our scaled down system.

Future Plans

The future plans for development of this system fall into two categories; process improvements and hardware improvements. First of all with the process improvements, during both the tests we only had air pressure of approximately 40 psi available to us. Therefore we would like to experiment with higher pressures 50, 60, and 70 psi to see if there is a change in the effectiveness of the cleaning and a reduction of the amount of time the catheters need to spend in the cleaning process. Second as mentioned above refine the air mixing system so that there is more control on the amount of air being mixed. More accurate valves and then further testing on different combinations of air and AK-225 can do this. Once these process improvements have taken place and the cleaning process proven out by further testing a full scale device can be build to clean 10 catheters at a time, and of both lengths.

Then there is the second category of hardware improvements. Most of these improvements were not included in our device due to budgetary constraints, but should be considered in future versions of this device. The addition of a 10 micron filter with in the line that transfers AK-225 from the catch tank back to the pressure vessel would allow particles be removed. This would ensure that they are not re-deposited on another catheter in a future cycle. Also in the current configuration a counter with in the PLC determines when the solvent level should be checked. Instead of this system a fluid level indicator could be added to one of the two tanks, giving a more accurate reading of the level of solvent available. Then in order to better ensure operator safety, we believe that a laser curtain should be added to the device to prevent the operator from getting hurt as a result of the manifold opening and

closing. The final hard ware improvement that we suggest would be a vaporized solvent recovery system that would try to reclaim some of the solvent lost in the exhaust process.

Appendix A, Engineering Drawings:

Table of Contents:

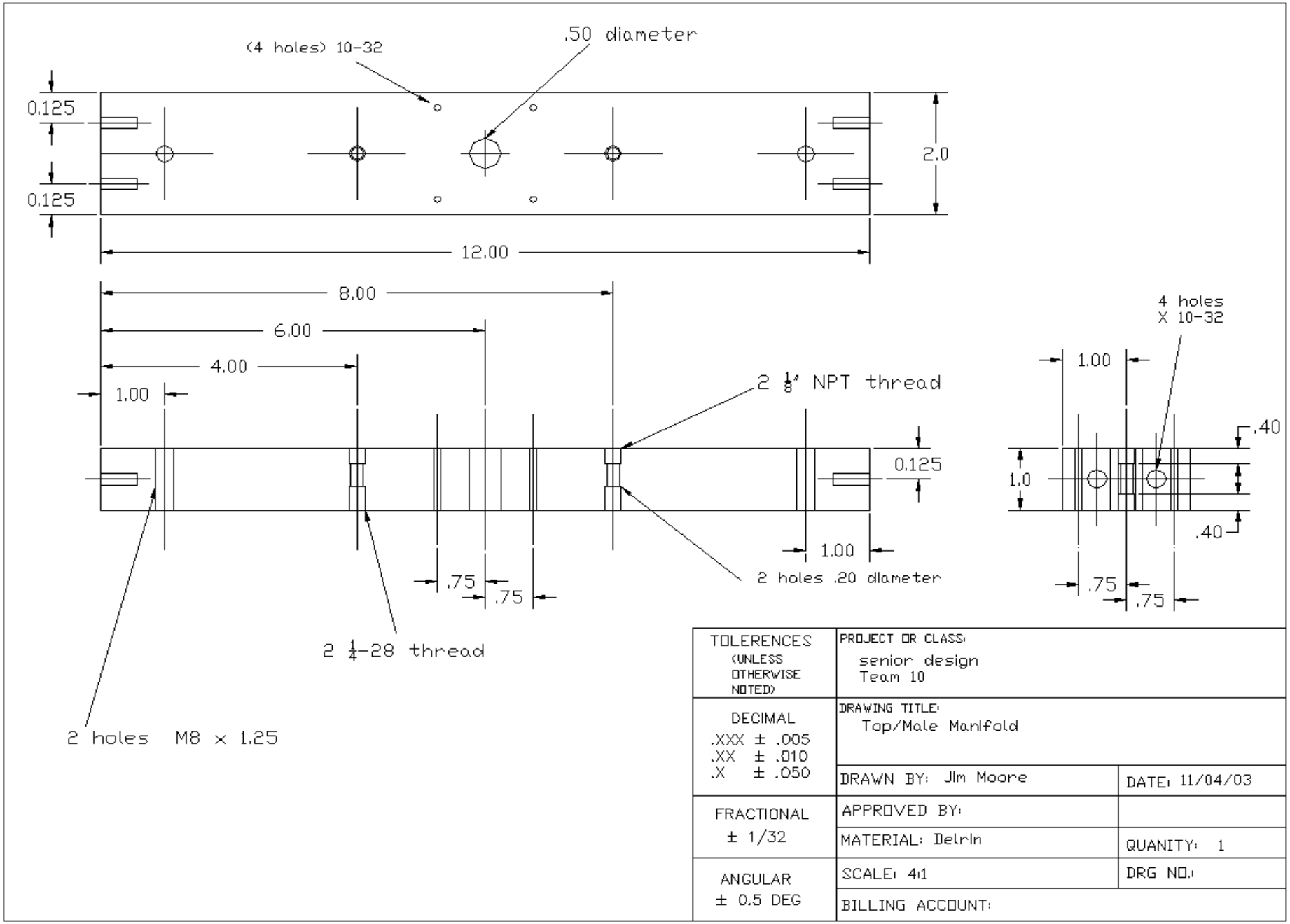
2-D Engineering Drawings:

- Drawing 1: Upper Manifold
- Drawing 2: Lower Manifold
- Drawing 3: Linear Bearing Brace
- Drawing 4: Air cylinder support
- Drawing 5: Base Plate

3-D Assembly Drawings:

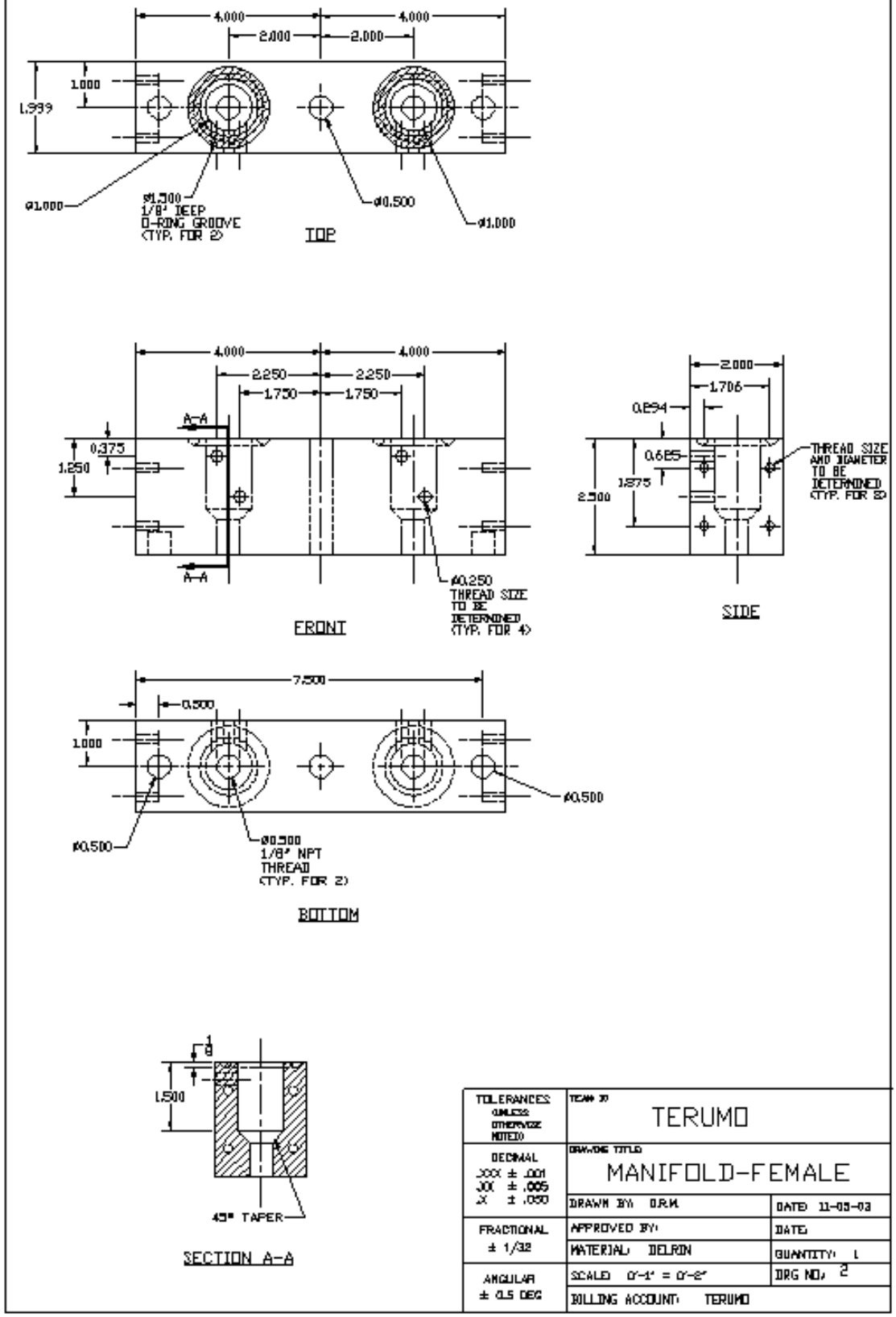
- Assembly Drawing 1, Exploded Assembly Drawing of Lower Portion, with part list
- Assembly Drawing 2, Exploded Assembly Drawing of Upper Portion, with part list
- Assembly Drawing 3, Exploded Assembly Drawing of Hose connections, with part list
- Assembly Drawing 4, Full Exploded Assembled Drawing, front isometric view
- Assembly Drawing 5, Assembled Drawing, Front view
- Assembly Drawing 6, Assembled Drawing, Rear isometric view
- Assembly Drawing 7,8,9; Hose connection Diagram, with assembly notes

Drawing 1: Upper Manifold

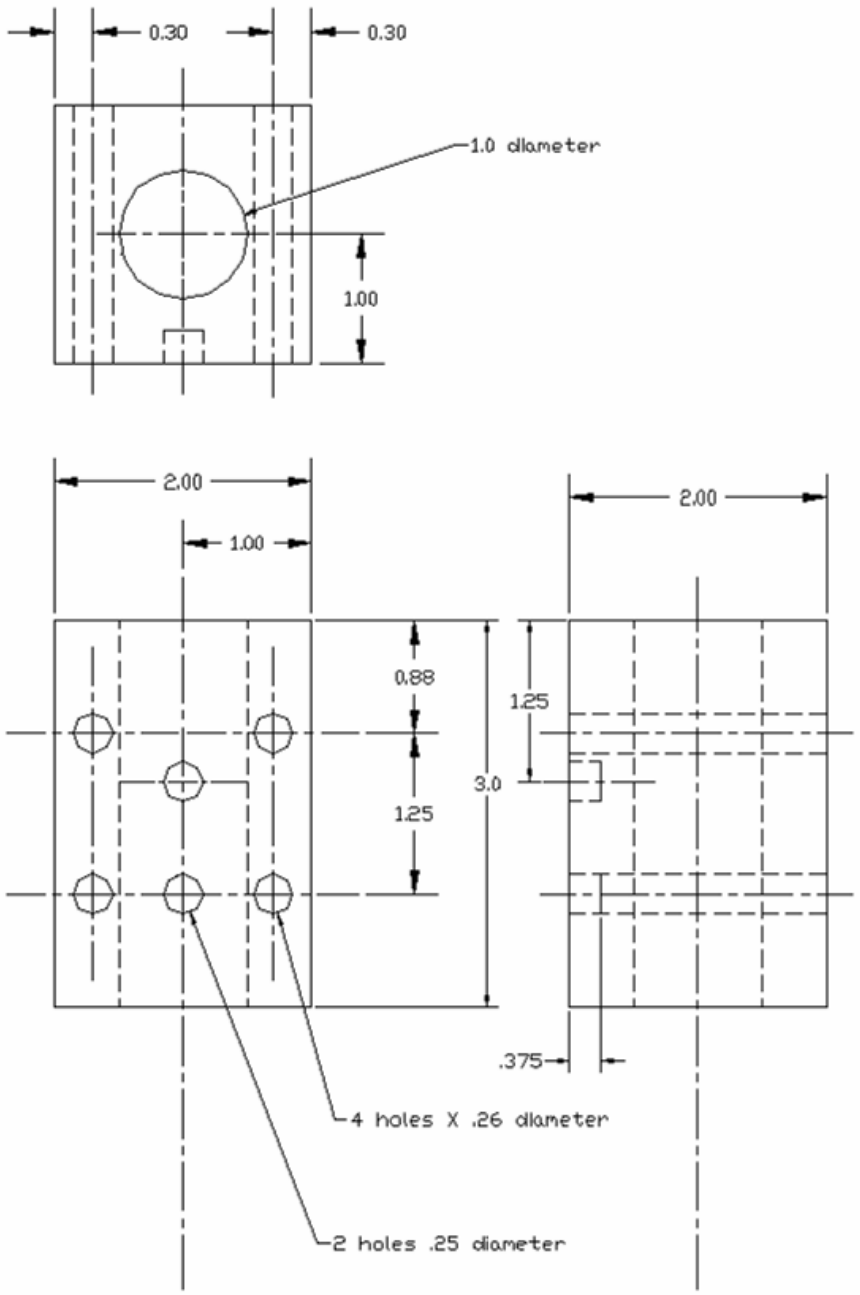


TOLERENCES (UNLESS OTHERWISE NOTED)	PROJECT OR CLASS: senior design Team 10	
DECIMAL .XXX ± .005 .XX ± .010 .X ± .050	DRAWING TITLE: Top/Male Manifold	
	DRAWN BY: Jim Moore	DATE: 11/04/03
FRACTIONAL ± 1/32	APPROVED BY:	
	MATERIAL: Delrin	QUANITY: 1
ANGULAR ± 0.5 DEG	SCALE: 4:1	DRG NO.:
	BILLING ACCOUNT:	

Drawing 2: Lower Manifold

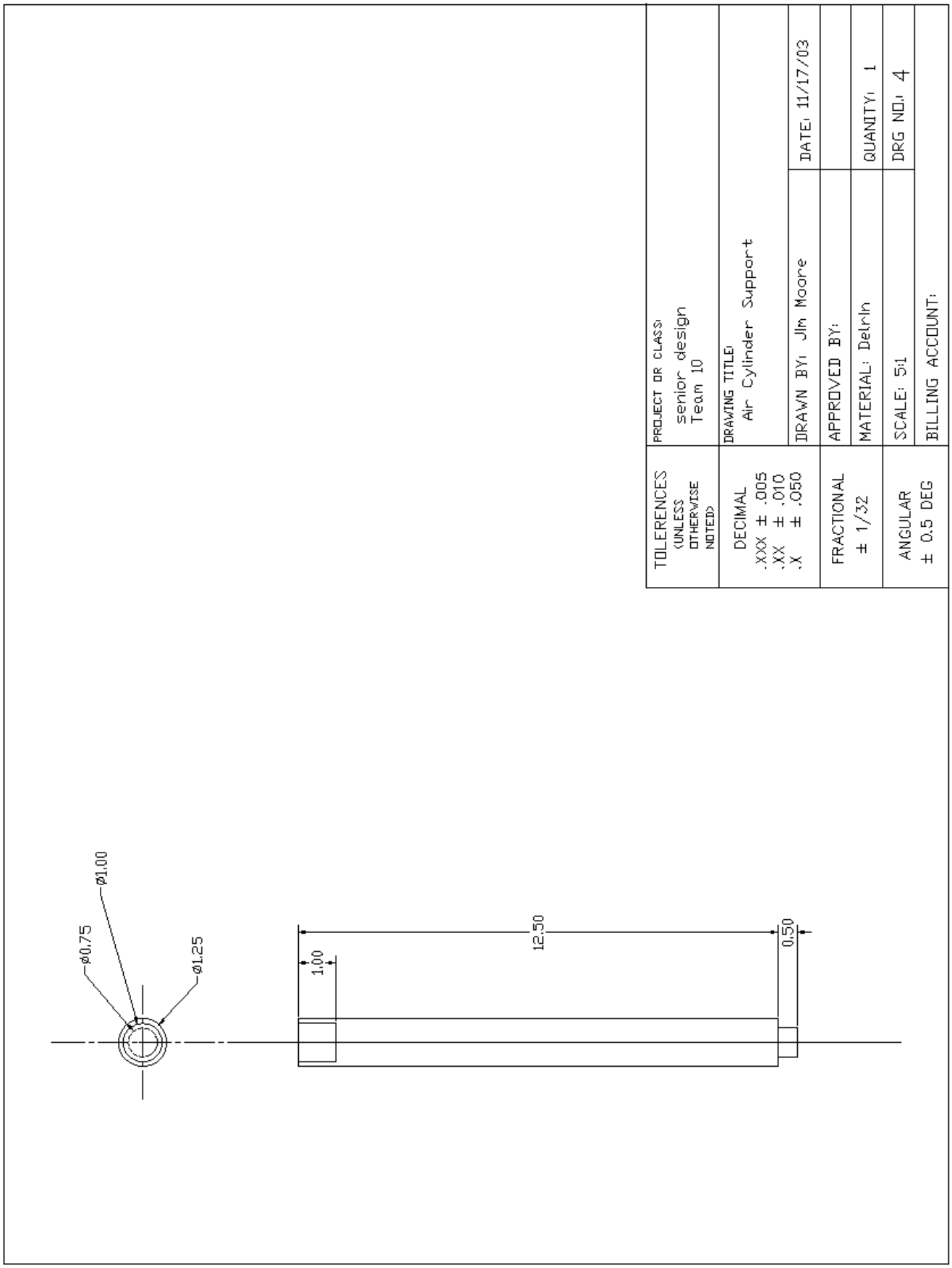


Drawing 3: Bearing Brace

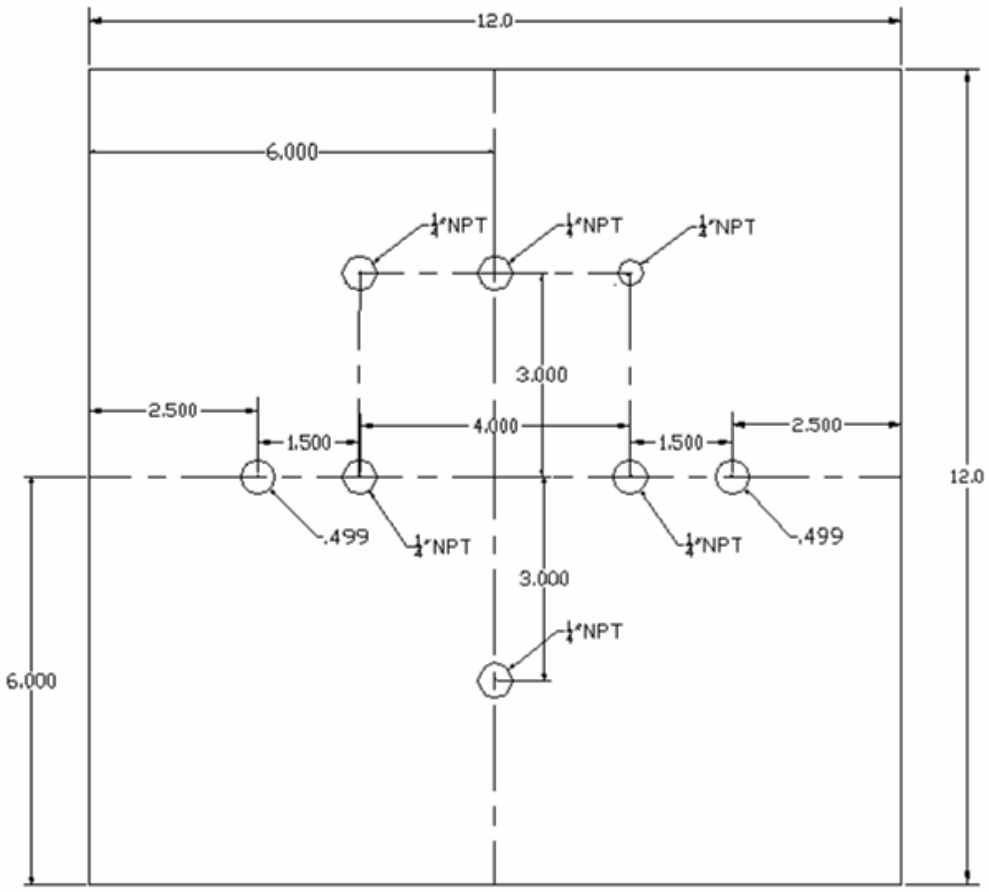


TOLERENCES (UNLESS OTHERWISE NOTED)	PROJECT OR CLASS: senior design Team 10	
DECIMAL .XXX ± .005 .XX ± .010 .X ± .050	DRAWING TITLE: Bearing Braces	
	DRAWN BY: Jim Moore	DATE: 11/04/03
FRACTIONAL ± 1/32	APPROVED BY:	
	MATERIAL: Delrin	QUANITY: 1
ANGULAR ± 0.5 DEG	SCALE: 4:1	DRG NO.: 3
	BILLING ACCOUNT:	

Drawing 4: Air cylinder support

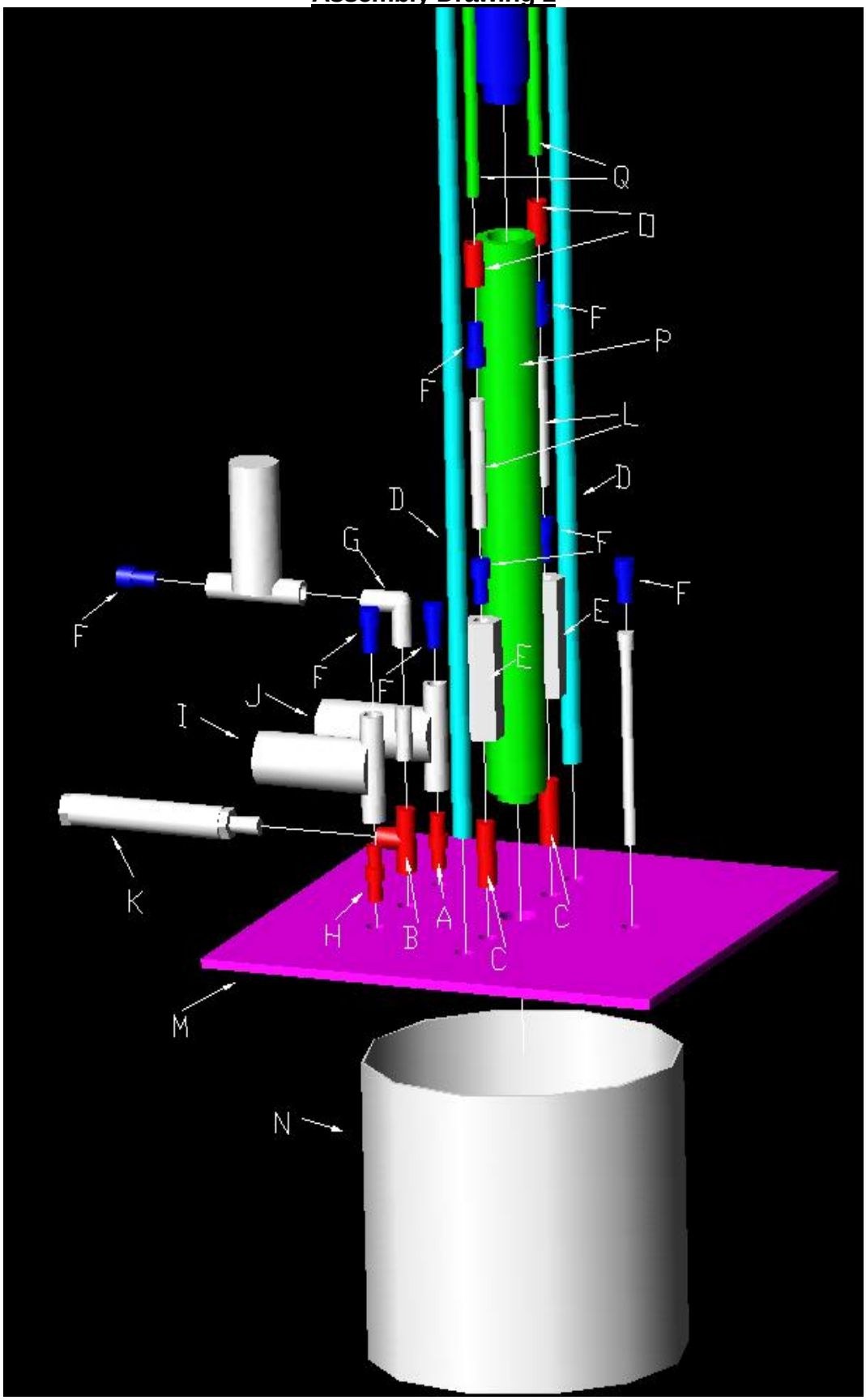


Drawing 5: Base plate



TOLERENCES (UNLESS OTHERWISE NOTED)	PROJECT OR CLASS: MEEG401	
DECIMAL .XXX ± .005 .XX ± .010 .X ± .050	DRAWING TITLE: Base Plate	
	DRAWN BY: JBlyer	DATE: 11-04-03
FRACTIONAL ± 1/32	APPROVED BY:	DATE:
	MATERIAL: ¼" Stainless Plate	QUANITY: 1
ANGULAR ± 0.5 DEG	SCALE: unknown	DRG NO.: 5
	BILLING ACCOUNT:	

Assembly Drawing 1

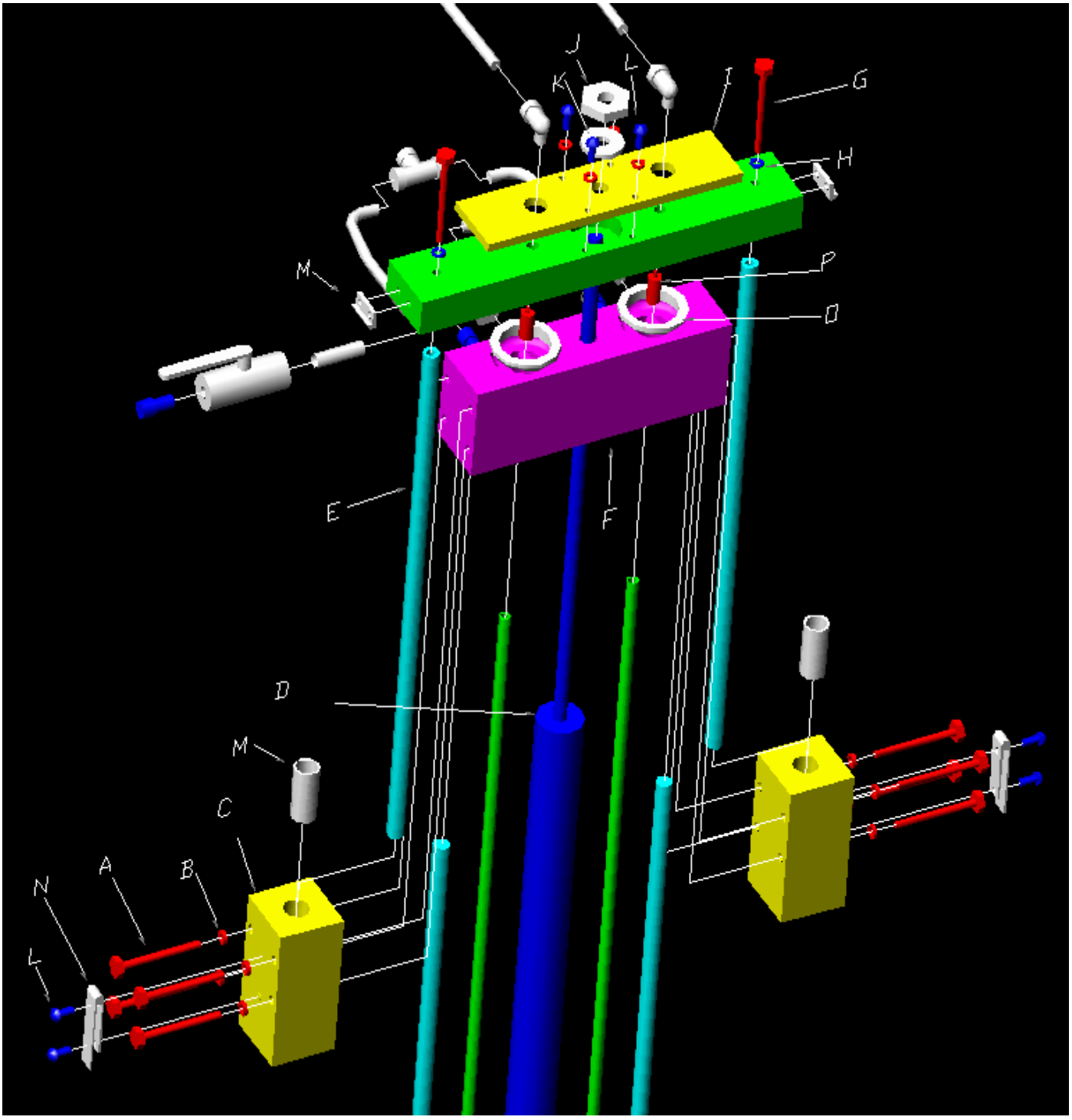


Assembly Drawing 1, parts list

Item	Description
A	1/4" NPT nipple (hex)
B	1/4"NPT male x male x female
C	1/4"NPT male x socket weld (1/2")
D	29" 1/2"Diameter 316 SS rod
E	1/4"NPT female x female, 316 Stainless Steel Check Valve
F	1/4"NPT x 3/8" tube compression fitting
G	1/4" NPT x 1/4" NPT Elbow
H	3/8"NPT Nipple (hex)
I	3/8"NPT Delrin Solenoid Valve
J	1/4"NPT Delrin Solenoid Valve
K	75Psi Pop-Safety valve
L	3/8"OD x 5/16"ID PTFE tube (cut to fit)
M	12" square machined plate (see drawing 5)
N	190 Psi stainless steel pressure tank, cut at 7 inches from bottom
O	1/8"NPT stainless steel coupler
P	Air Cylinder Support (see drawing 4)
Q	1/8" NPT, 316 SS pipe, 17"

Assembly note:
Pressure tank, (N), 1/8” fillet welded to 12” square plate (M) around exterior circumference
Items D, C and E are press fitted and 1/8” fillet welded to 12” plate

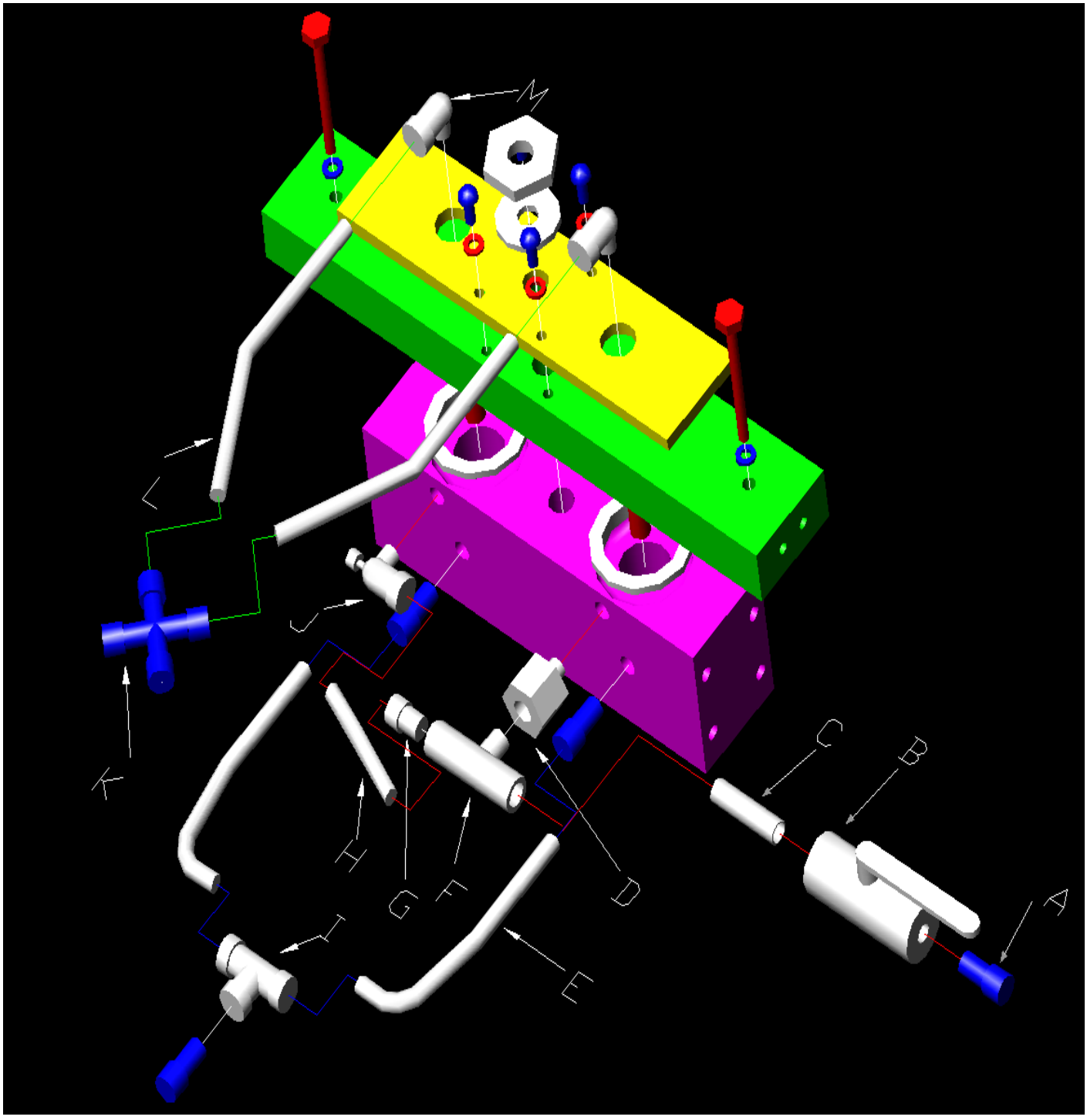
Assembly Drawing 2



Assembly Drawing 2, Parts list

A	5/16" hex head 1/4"-20 bolt
B	#10 washer
C	Linear Bearing Block (see drawing 3)
D	SMC 150 PSI air cylinder
E	1/2"OD x 15" long Linear Bearing Rods
F	Delivery Manifold (see drawing 2)
G	5/16" hex head 1/4"-20 bolt
H	#10 washer
I	Steel Support Plate (see drawing 6)
J	1/4"-20 Nut
K	1"OD x 3/16" ID Washer
L	10-24 cap head screw
M	Linear Bearing
N	5" Steel Clasp
O	2" OD x 1.5" ID, 3/16" radius faucet gasket

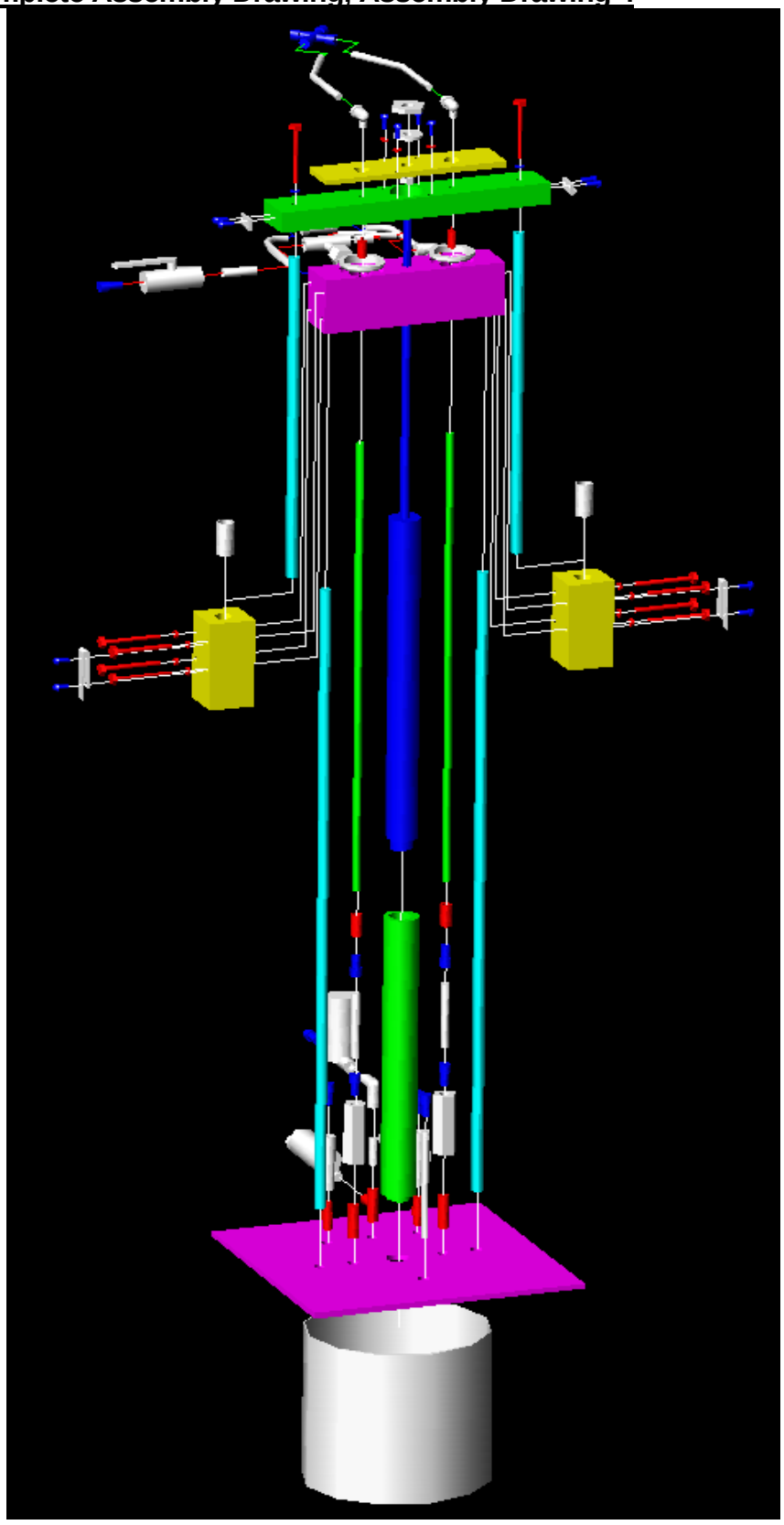
Assembly Drawing 3



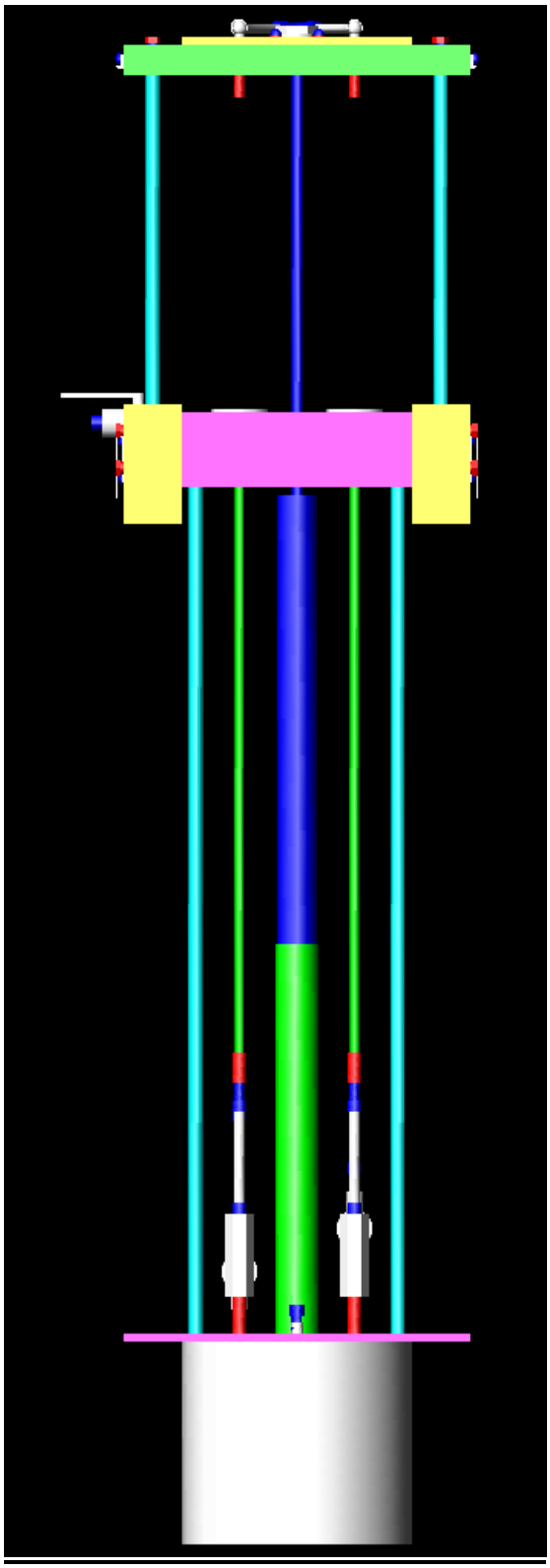
Parts list, Assembly Drawing 3

A	1/4"NPT x 3/8" tube compression fitting
B	1/4" x 1/4" Ball valve
C	1/4" x 1/4" x 1"long, round nipple
D	1/8" male x 1/4" female reducer
E	3/8"OD x 5/16" ID PTFE tubing, cut to fit
F	1/4" male x female x female pipe fitting
G	1/4"NPT x 1/4" hose push to fit connector
H	1/4" OD x 3/16" ID PVC hose
I	3/8" compression fitting Tee
J	1/8"NPT x 1/4" push to connect tube, air flow control valve
K	4 way, custom, 3/8" Compression fitting
L	3/8"OD x 5/16" ID PTFE tubing, cut to fit
M	3/8" tube compression fitting x 1/8" NPT, Elbow

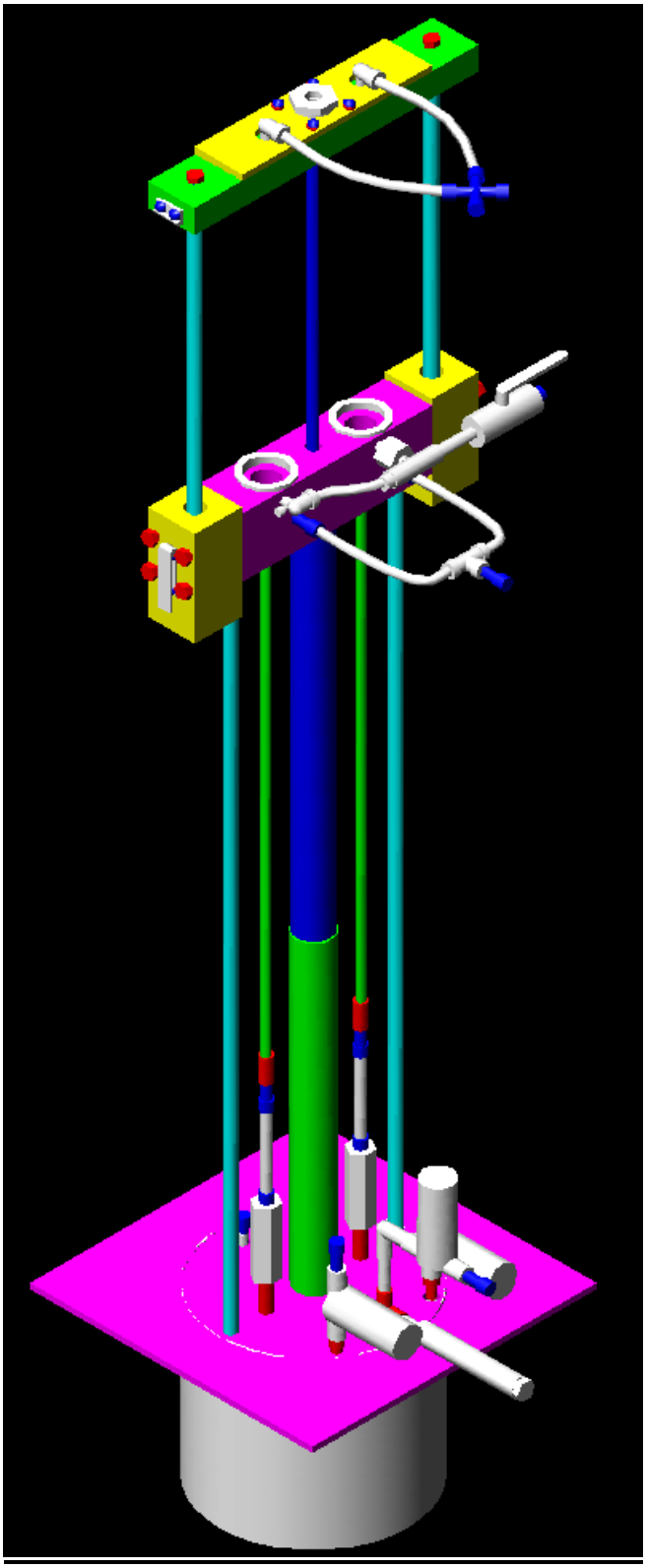
Complete Assembly Drawing, Assembly Drawing 4



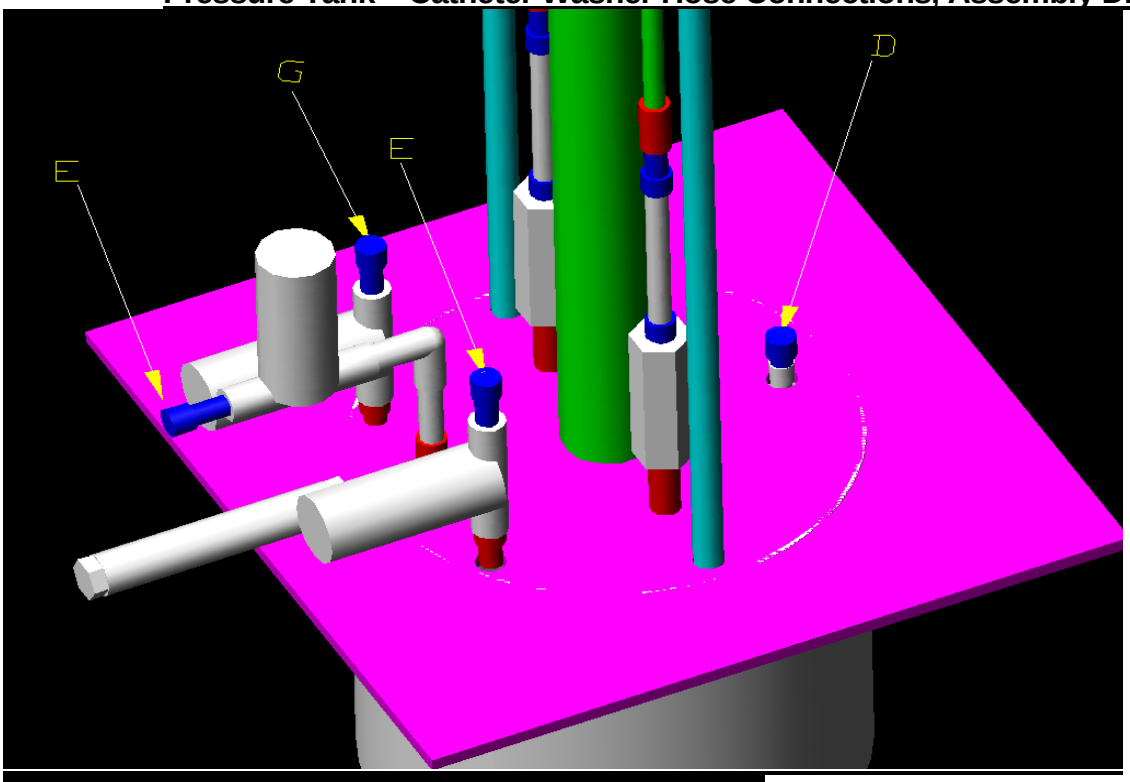
Assembled Drawing, Front View, Assembly Drawing 5

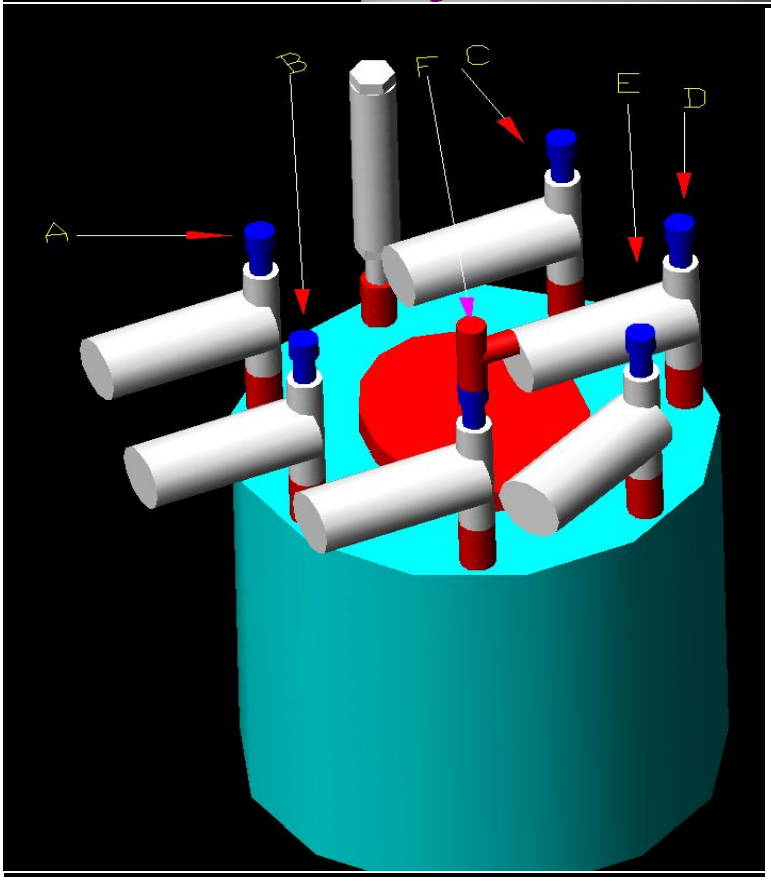


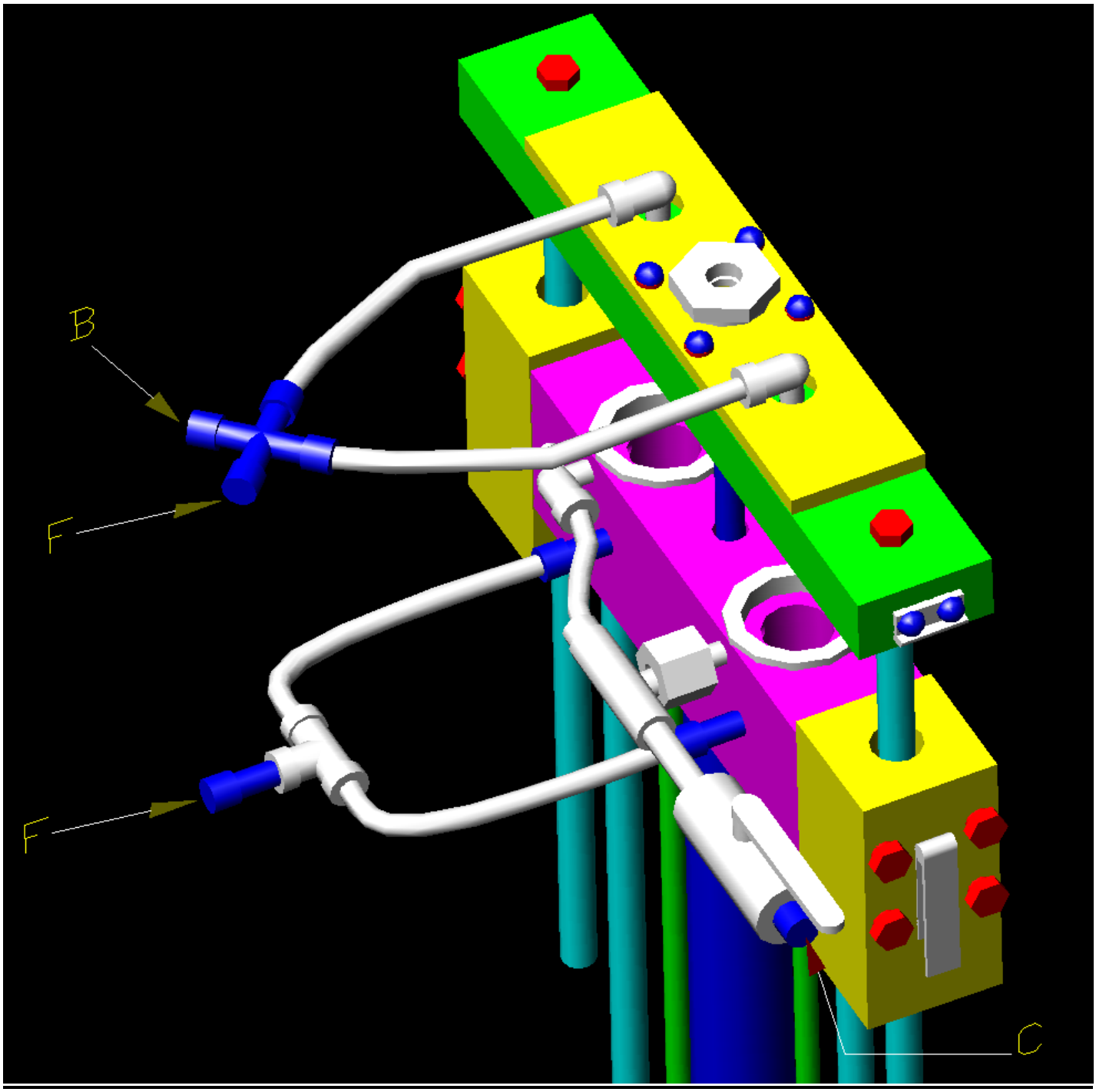
Assembled Drawing, Rear Isometric View, Assembly Drawing 6



Pressure Tank – Catheter Washer Hose Connections, Assembly Drawing 7,8,9







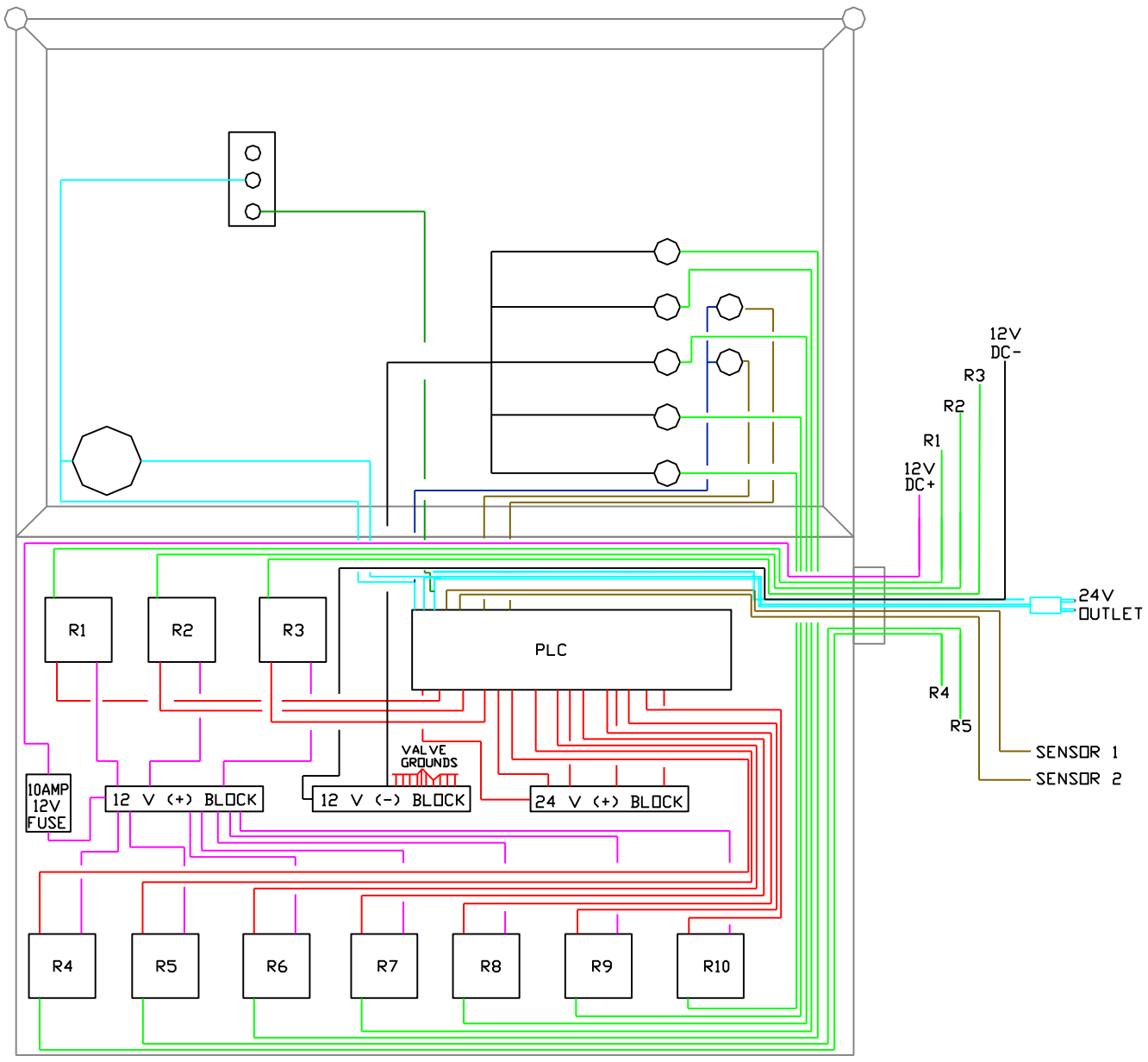
Connection Instructions:
-Connections labeled with corresponding letters connected with 3/8”OD x 5/16” ID PTFE Tubing, cut to fit.
-All connections are compression fittings.
-Connections A and G are connected to compressed air supply, regulated to 50 PSI
-Connections E (3 places) are pressure relief valves, with exhaust tubing leading to in house exhaust.

Appendix B

The following is a listing of all the materials used and their sources.

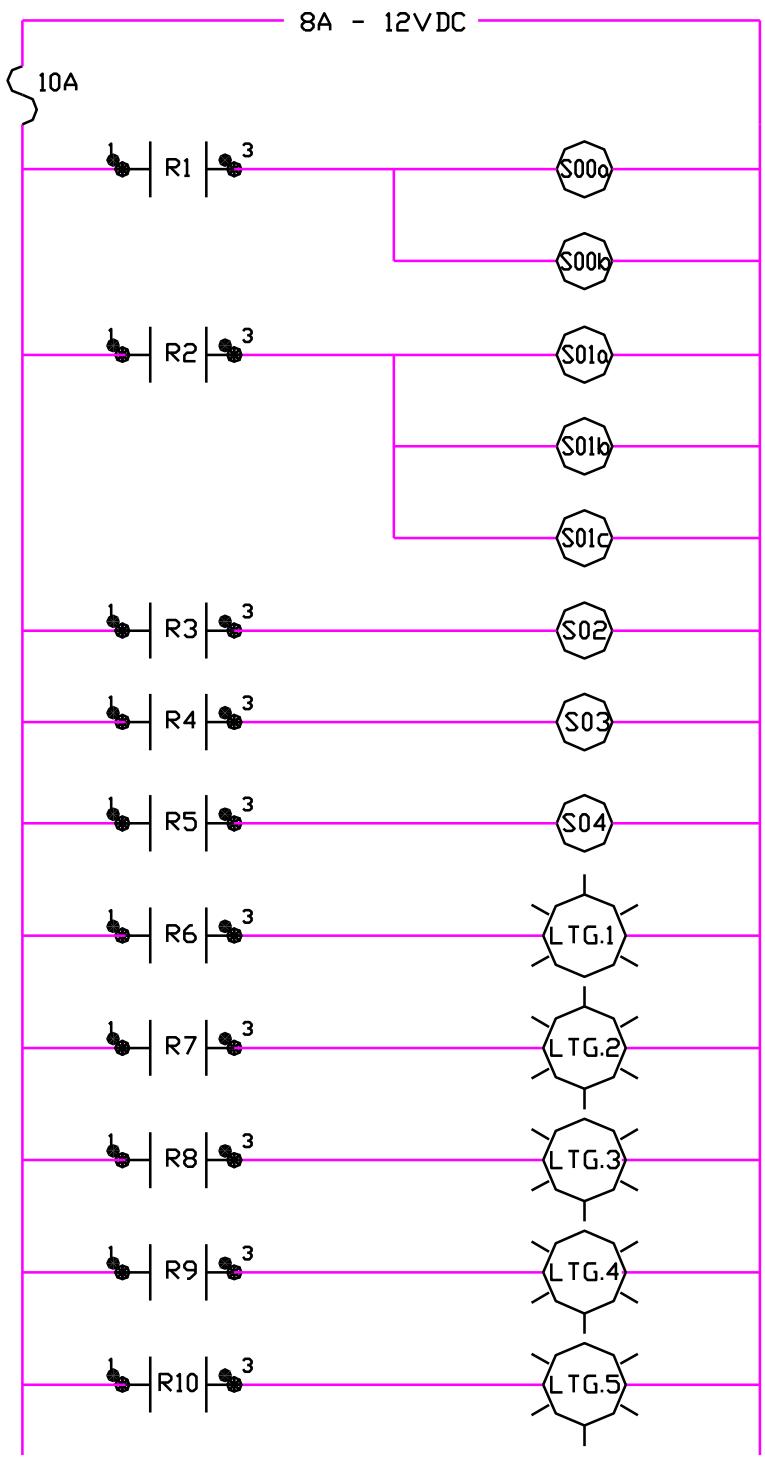
Purchased/Donated items:						
Description	**Company**	**Company #**	**Obtained from**	**item #**	**price**	**qty.**
Check Valves	Deltrol Fluid Products	EC-2088-0703	Purchased from McMaster Carr	#47885k91	$40.42	2
1/4" NPT male, 75 Psi Pop-Safety valves	Pop-it	CRN0631441c	Purchased from McMaster Carr	#98905k15	63.19	2
Pneumatic Cylinder	SMC	CDM2B25-300	Donated			1
Pnuematic Controller	SMC	sy5120-SLOZE-c6-f2	Donated			1
Pneumatic Exhaust/Filter	SMC	AMC320-01	Donated			1
Cylinder Location indicators	SMC		Donated			
Regulator Valve 40-100psi	Nullmatic	14870-7s6EJ	Borrowed			1
1/8" NPT pipe, schedule 80, 24"			Purchased from McMaster Carr	#68045k11	46.6	2
Delrin Solenoid Valve (1/4" NPT)			Purchased from McMaster Carr	#7876k58	34.38	7
YOR-LOK Compression Tee, tubex tube x male for 3/8" tubeOD, 14"NPT			Purchased from McMaster Carr	5182k187	22.06	5
1/4" NPT x 1/8" NPT nipple			Purchased from McMaster Carr	51205k191	5.8	2
1/4" NPT x 1/4" NPT hex nipple			Purchased from McMaster Carr	51205k132	4.82	4
YOR-LOK Straight Compression fitting for 3/8" tube OD x 1/4 NPT male			Purchased from McMaster Carr	5182k119	7.18	10
PTFE tubing 3/8" OD x 5/16" ID			Purchased from McMaster Carr	51805K73	1.94/foot	30 feet
Luer lock tube fittings Male Leur x 1/4"-28 male thread			Purchased from McMaster Carr	5194k13	10.26	2
YOR-LOK Straight Compression fitting for 3/8" tube OD x 1/8 NPT male			Purchased from McMaster Carr	5182k811	6.46	3
High Pressure fitting 1/4" NPT female x 1/8" Male			Purchased from McMaster Carr	51205k187	10.24	3
One end threaded nipple, 14" NPT			Purchased from McMaster Carr	9157k21	1.07	2
1/8" NPT Coupler			Purchased from McMaster Carr	4452k441	1.87	1
Portable SS Pressure tank			Purchased from McMaster Carr	41705k39	200	2
Full Port Ball Valve			Purchased from McMaster Carr	46495k58	21.82	1
1/8" NPT x 5/16" tube Flow control valve			Purchased from McMaster Carr	4816k13	15.89	1
2" OD x 1.5" ID x 3/16" radius faucet gasket			Purchased from Sears Hardware		5	2
Square D, Plug in Relay 24v-12v	Square D		Donated			
Square D, TYPE KP Relay Terminal	Square D		Donated			
Emergency Stop Switch	United Electric Company		Donated			
10A, DC Fuse with carrier	United Electric Company		Donated			
2' x 1' x 1' Fiberglass Electrical Cabinet	United Electric Company		Donated			
12 v Push Switch			Purchased from Sears Hardware		2	2
12 v indicator lights			Purchased from radio shack		2	5
OMRON PLC Controller, 12 outputs			Donated			
Teflon Tape			Purchased from Sears Hardware		2	4 rolls
10-24 cap head screws, 3/8" long					8	
1/4-20 Hex Bolts, 2.5" long					10	
#10 washer					12	
1/4-20 Hex Nut					1	
1/2 "Linear Bearings			Purchased from McMaster Carr	6630k13	2	42.57
Raw Material sizes						
Material	**Size**	**Used for**				
Stainless Steel, type 304	12" x 12" x .25"	Base Plate				
Stainless Steel, type 316	1.25" Diameter x 15" long	Cylinder support				
Stainless Steel, type 316	1/2" diameter x 50 " long	Support Rods				
Delrin	2" x 1" x 12'	Upper manifold				
Delrin	2" x 2" x 8"	Lower manifold				
Miscellaneous Steel Stock		Custom Nuts and washers				

Appendix C Electrical Drawings



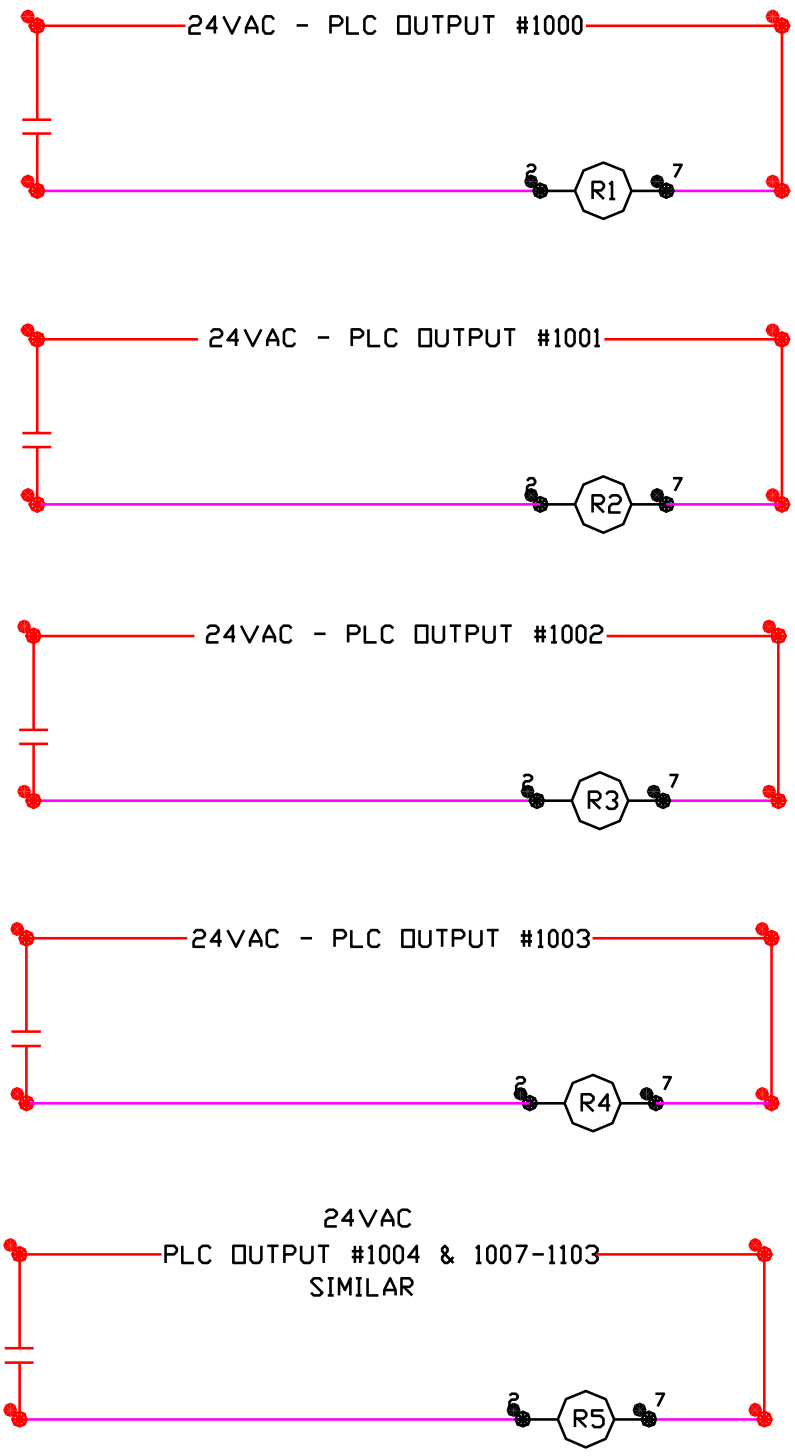
ENCLOSURE (OPEN)

(NO SCALE)



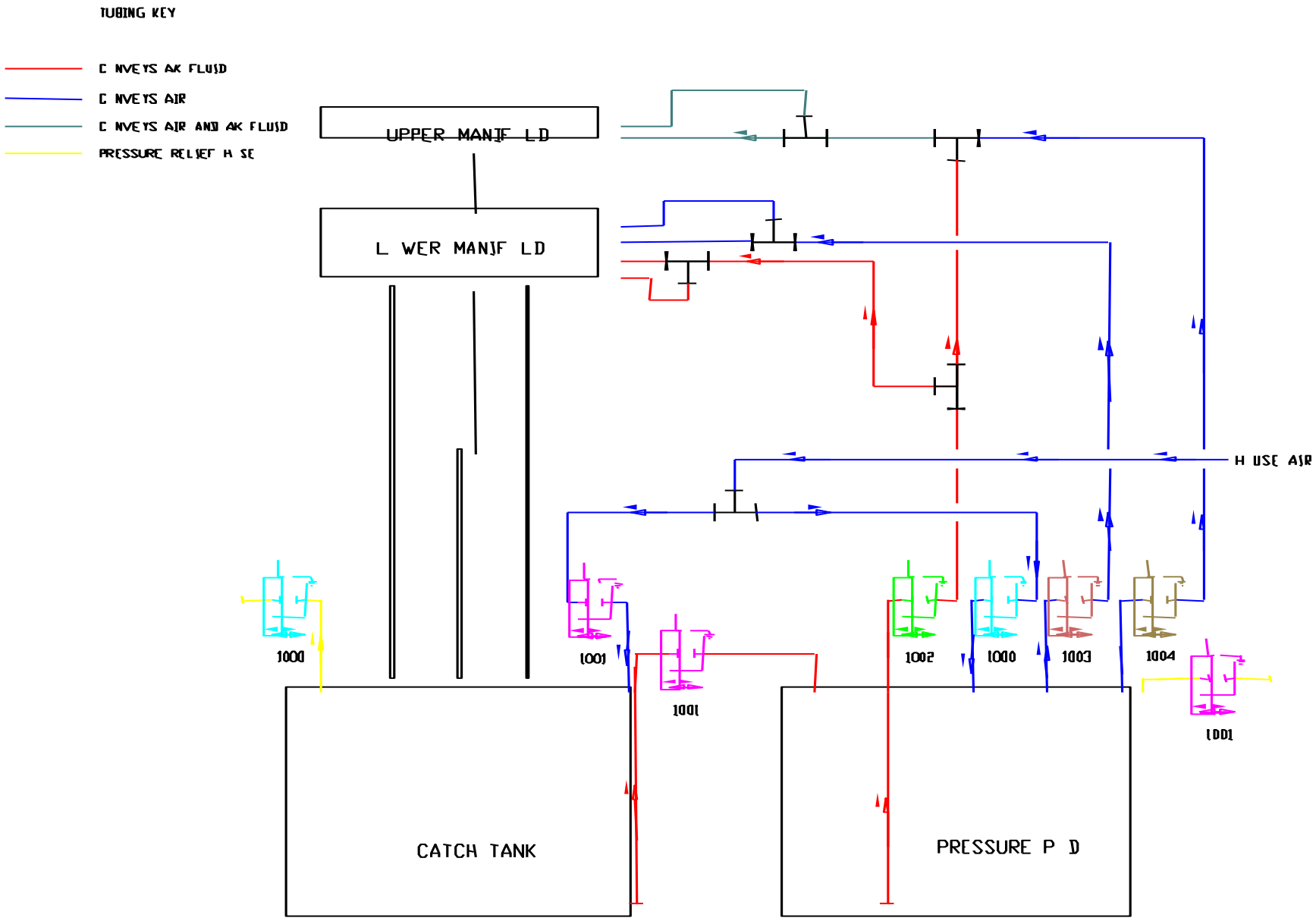
SINGLE LINE WIRING DIAGRAM

(NO SCALE)



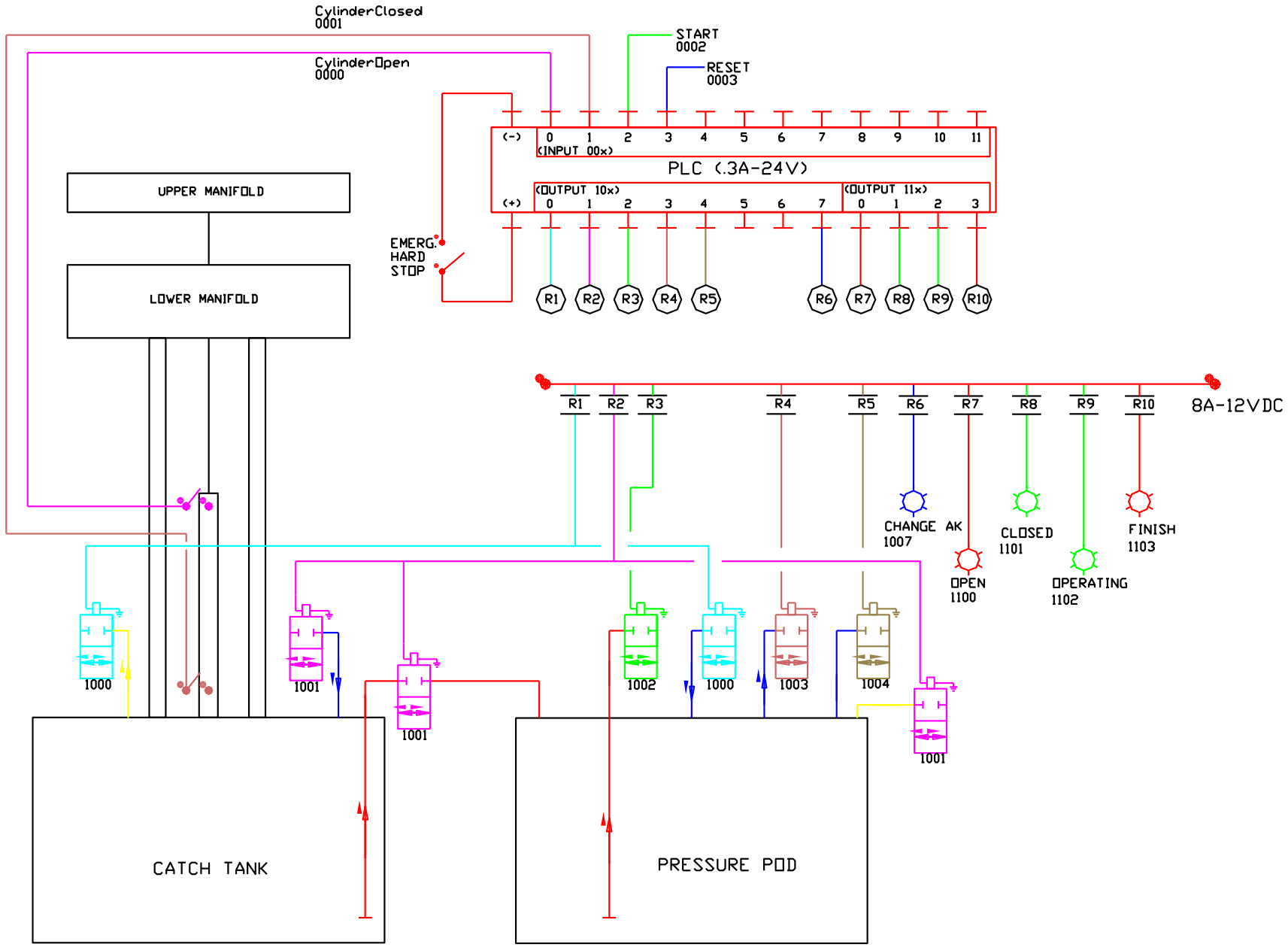
SINGLE LINE WIRING DIAGRAM

(NO SCALE)



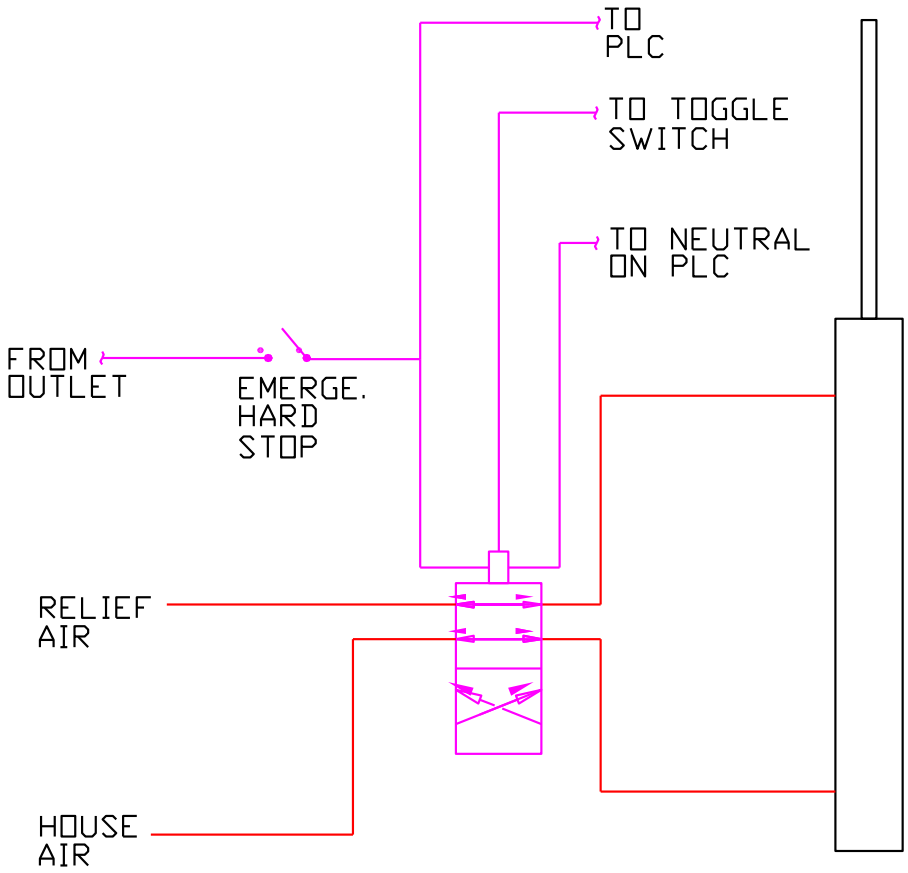
PLUMBING DIAGRAM

(N SCALE)



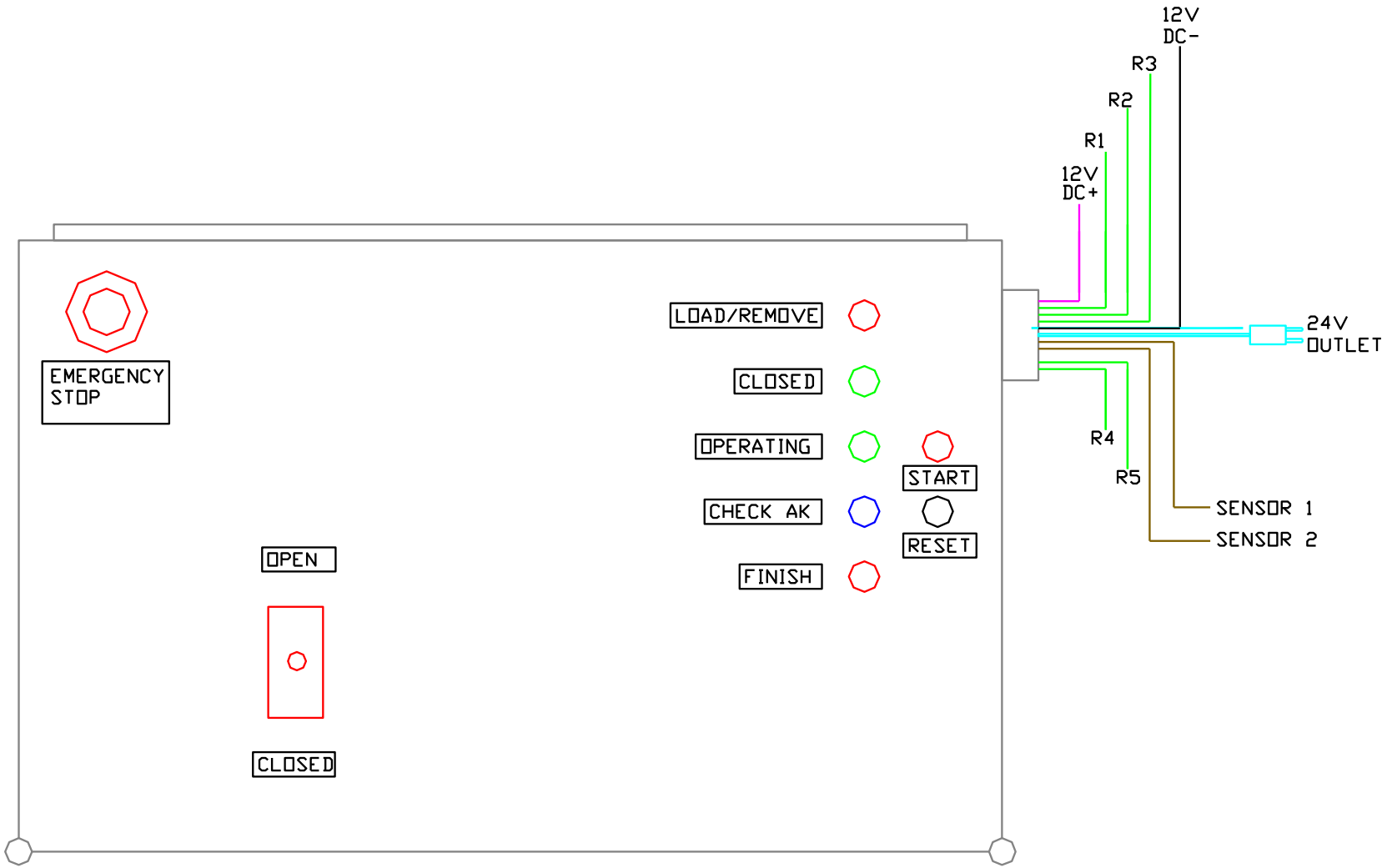
PLC WIRING LAYOUT

(NO SCALE)



PNEUMATIC CYLINDER DIAGRAM

(NO SCALE)



ENCLOSURE (CLOSED)

(NO SCALE)

Appendix D

Operation and Maintenance Manual

Operations:

A. Initial Checks (to be done before operating machine)

1. Visually inspect the electrical connections from the solenoid valve, pneumatic cylinder, and sensors to make sure none of them have come lose.

2. Plug in the external power supply, 110 VAC for the control panel and 12 VDC fro the valves. Then test the emergency stop button to make sure it is working properly.

3. Check AK-225 level it should be filled with ¾ of a gallon at the start. (Note: the system can run on less, this is an initial level suitable for cleaning a batch of catheters)

4. Connect/open the in house air, allowing it to flow to the regulators.

5. When the first cycle begins inspect the gaskets between the manifolds for wear and replace as necessary.

B. Running the Cleaning Cycle

1. Use the switch on the control panel to raise the pneumatic cylinder and open the manifold. Red Load/Unload light should turn on.
   a. If pneumatic cylinder fails to raise
      i. Check the latches are completely open
      ii. Check electrical connections
      iii. Check regulator connection, and amount of pressure
   b. If light fails to turn on but cylinder is physically open
      i. Check sensor connections
      ii. Check sensor positions
      iii. Check electrical connections

2. Once the upper manifold has come to a stop (in the raised position), feed the catheters into the lower manifold and twist into the luer lock using a ¼ turn.
   a. If lower manifold is flooded with AK-225
      i. Physically open pop-it valve on catch tank
      ii. Check gaskets for damage

3. Check that the gaskets are sitting flat in the grove openings around each catheter in the lower manifold.

4. Use the switch on the control panel to lower the pneumatic cylinder and close the manifold (Note: keep hand away from manifolds during this operation) Red Load/Unload light should turn off, and green Closed light should turn on.
   a. If pneumatic cylinder fails to lower
      i. Check electrical connection
      ii. Check regulator connection
   b. If green light fails to turn on
      i. Re-open cylinder and check that the gaskets are sitting flat in their grooves, then lower the cylinder
      ii. Check the electrical connections
      iii. Check the regulator pressure
      iv. If the upper and lower manifold are sealed with enough pressure then, check the sensor position

5. Close the latches on both sides of the manifold.
   a. If the latches fail to close
      i. Re-open cylinder and check that the gaskets are sitting flat in their grooves, then lower the cylinder
      ii. Check the regulator pressure

6. Press the start button, green Operating light should turn on.
   a. If start button fails to begin process
      i. Check that blue check AK light
         1. if it is on, use pop-it to relieve pressure, check AK level and press the reset button
      ii. Check that steps 4-5 have been completed
      iii. Check electrical connections

7. The system will go through its tasks at this point. If any problems occur the system will stop abruptly and an indicator light(s) will illuminate displaying an error message. Also if the operator notices anything odd occurring then the emergency stop button can be pressed to halt the process. (Note: if the manifold needs to be opened in order to correct the problem the cleaning process will start over from the beginning)
   a. If closed light turns off
      i. Check the regulator pressure
      ii. Check the electrical connection
      iii. Check the sensor position
   b. If check AK light turns on
      i. Physically open the pop-it valve to relive pressure
      ii. Check the AK level
      iii. Press the reset button
      iv. If the light fails to turn off hit emergency stop and check wiring
      v. If the light does turn off then hit the start button
   c. If the Load/Unload light comes on

i. Hit the emergency stop and check wiring

d. If the AK does not seem to be flowing into the lower manifold
   i. Adjust the ball valve so that it is less open
   ii. Check the AK level
   iii. Check electrical conections

e. If the AK fails to flow into the upper manifold or out of the catch tank
   i. Check the electrical connections
   ii. Check the AK level
   iii. Check the solenoid valves
   iv. Check the check valves

8. When the system is done the red finish light will turn on, telling the operator that the catheters can be removed, and another operation can be run.
   a. If the finish light fails to turn on after the cycle is obviously done
      i. Check the electrical connections
   b. If the cycle fails to stop with in the normal length of time
      i. Hit emergency stop and check the electrical connections

9. Unlatch both sides of the upper manifold

10. Use the switch on the control panel to raise the pneumatic cylinder and open the manifold. Red Load/Unload light should turn on.
    a. If pneumatic cylinder fails to raise
       i. Check the latches are completely open
       ii. Check electrical connections
       iii. Check regulator connection, and amount of pressure
    b. If light fails to turn on but cylinder is physically open
       i. Check sensor connections
       ii. Check sensor positions
       iii. Check electrical connections

11. Once the upper manifold has come to a stop (in the raised position), unload the catheters from the lower manifold and twist out of the luer lock using a ¼ turn.
    a. If lower manifold is flooded with AK-225
       i. Physically open pop-it valve on catch tank
       ii. Check Gasket for damage

12. Repeat until all catheters are clean

Note: When ever checking the electrical connections, make sure the emergency stop is presses if working on the external connections. If working inside the control box unplug the entire system.

Emergency Procedure:

If at any point during the running of the machine it looks like there may be something wrong, such as abnormal vibration, leakage, fire, structural failure, and (or) anything that may cause concern for your well being or the well being of the people around you, do the following:

1. Immediately hit the “Emergency Stop” button, located in the top left hand corner of the enclosure
2. Press the Manual Pressure Relief buttons located on the top of both the Catch Tank and Pressure Pod.
3. Unplug the Car Battery Charger and the Machine
4. Alert your supervisor and the floor Engineer to the problem
5. Before starting back up, verify that the Pressure Pod’s lid is on securely.
6. With the permission of the floor Engineer, plug the machine and Car Battery Charger back into the wall socket.
7. Pull out the “Emergency Stop” switch
8. The Machine is now ready to run again.

Maintenance:

A. Valves: All valves within the system should be removed an air tested to ensure proper functionality after at least every500 runs.

B. Hoses: All hoses should be replaced after at least every 500 runs.

C. Sensors
   1. The operator should run a quick diagnostic system check after every start-up of the machine.
      a. If any sensors fail the test, they must be removed and replaced before the next run.

D. Frame: The system’s frame must be checked for sturdiness by the maintenance department after at least every 500 runs.

Appendix E

Weld Analysis of main weld on pressure pot to steel plate

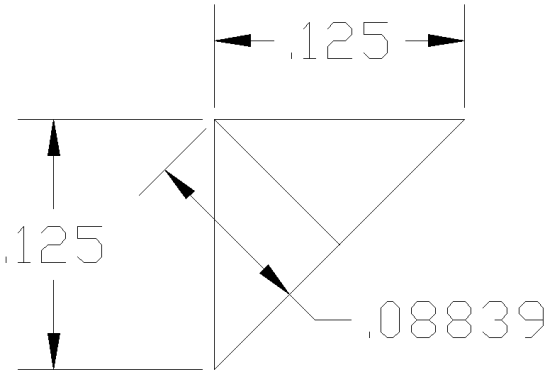
Calculating the equivalent force on the plate due to the pressure

$$\mathrm{Pr}essure = 100 lbs / in^2$$

$$Area = \frac{\pi d^2}{4} = 63.62 in^2$$

$$Force = \mathrm{Pr}essure \bullet Area = 100 \frac{lbs}{in^2} \bullet 63.62 in^2 = 6361.725 lbs$$

1/8" weld, has a .0884 in throat



The throat of the weld is the weakest part of the weld, therefore it must be checked for strength

Extruding the throat of the weld around the 9in diameter gives a surface area of:

$\frac{\pi \bullet (((9 + (2 \bullet .125))^2 - 9^2)}{4}$ =3.584in^2

Calculating the Sheer Stress on this area:

$$\sigma = \frac{F}{A}$$

$\sigma = \frac{6361.725 lbs}{3.584 in^2}$ =1775.342 lbs/in^2

The yield stress of type 304 Stainless steel is 25000psi
This gives a factor of safety to yielding of:

$\frac{25{,}000\, psi}{1775.342\, psi} = 14.1$, Now that's a safe weld.